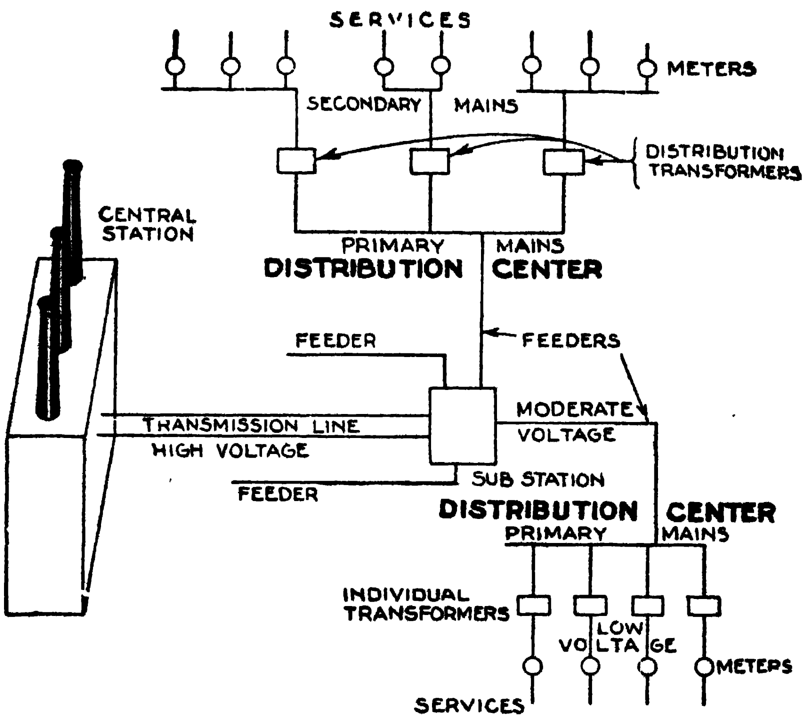

Typical Overhead Transmission and Distribution System Showing Central Station, Sub-Station, Distribution Centers, etc.

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VOL. VII

FOR ENGINEERS, ELECTRICIANS
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Foreword

This series is dedicated to Electrical Progress—to all who have helped and those who may in the coming years help to bring further under human control and service to humanity this mighty force of the Creator.

The Electrical Age has opened new problems to all connected with modern industry, making a thorough working knowledge of the fundamental principles of applied electricity necessary.

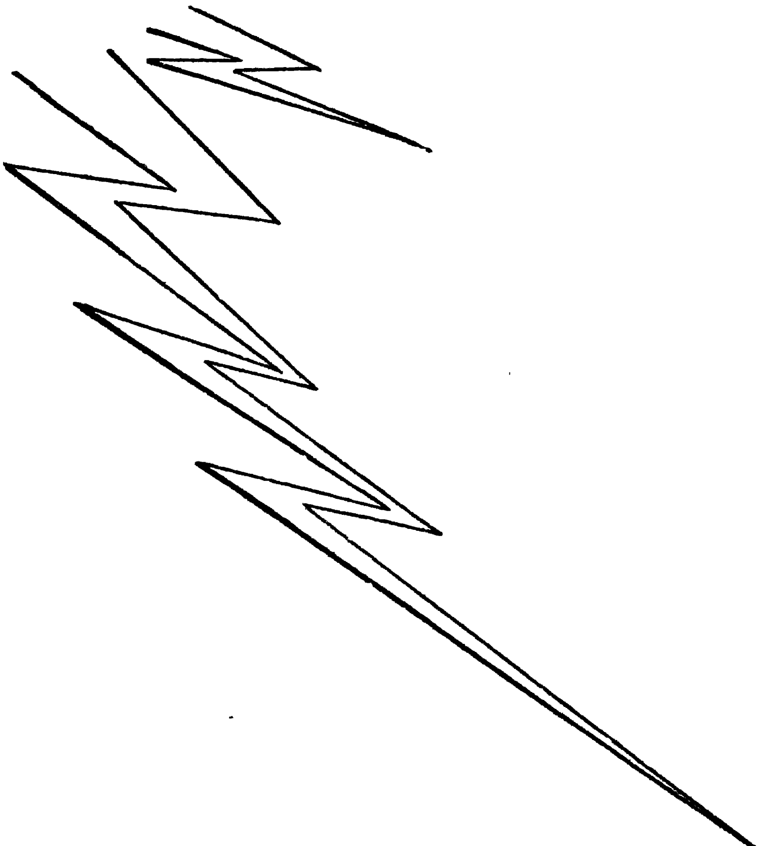
The author, following the popular appeal for practical knowledge, has prepared this progressive series for the electrical worker and student; for all who are seeking electrical knowledge as a life profession; and for those who find that there is a gap in their training and knowledge of Electricity.

Simplicity is the keynote throughout this series. From this progressive step-by-step method of instruction and explanation, the reader can easily gain a thorough knowledge of modern electrical practice in line with the best information and experience.

The author and publishers here gratefully acknowledge the hearty and generous help and co-operation of all those who have aided in developing this helpful series of Educators.

The series will speak for itself and "those who run may read."

The Publishers.



How to Use This Book

Finder

IMPORTANT

To quickly and easily find information on any subject, read over the general chapter headings as shown in the large type—this brings the reader's attention to the general classification of information in this book.

Each chapter is progressive, so that if the reader will use the outline following each general chapter heading, he will readily come to the information desired and the page on which to find it.

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"An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence."

FINDER

Pages

97 Wires and Wire Calculations ....2,999 to 3,040

98 Power Wiring.....................3,041 to 3,082

CHAPTER 95

House Wiring

The wiring of finished houses is not as easy as it may appear, as there are no two houses built alike, and there are no two wiremen who would wire the same house in the same manner.

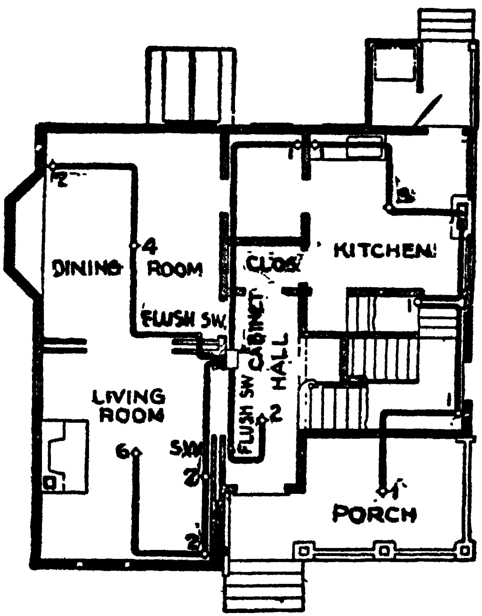


FIG. 5,560.—Plan showing one floor of a dwelling wired with conduits. The numbers on the various outlets indicate the number of lamps supplied. The wiring is carried out on the loop system, and it will be noticed that no branches are taken off between outlets. Four circuits are used in order that there may not be more than ten lamps on any one circuit.

Then there are numerous setbacks that make it difficult to proceed with the work quickly, such as parquet floors, double floors, clogged partitions and other obstructions which are met with: but if the instructions be carefully followed no difficulty will be experienced.

By laying out the job and drawing a rough sketch much labor and material will be saved.

In many cases the only instructions given the electrician who does the wiring is simply a plan showing the location and number of lights, from

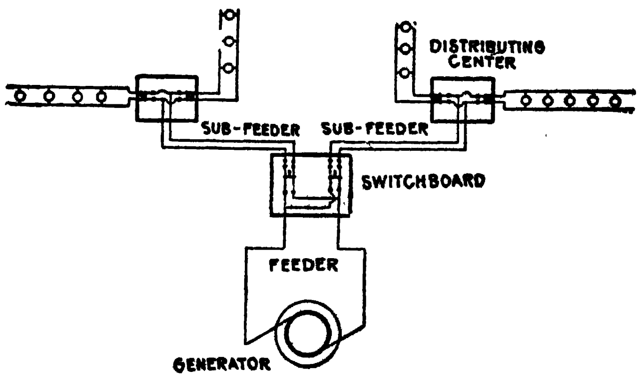
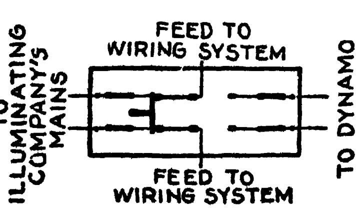


FIG. 5,561.—Two wire parallel system as used in isolated plant.



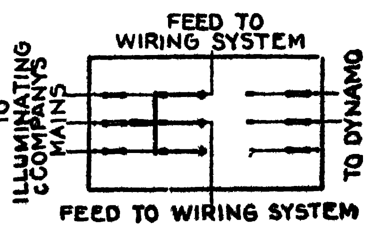


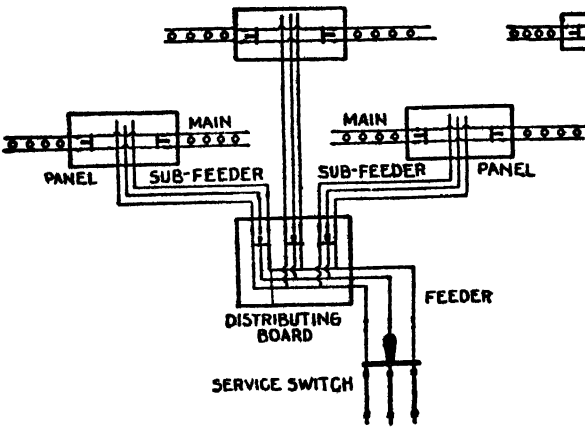
FIG 5,562.—Double throw switch for use in isolated plants when auxiliary power is used from the central station in case of breakdown.

FIG. 5,563.—Double throw three pole switch for use in isolated plants where auxiliary power is brought in through three wire system. The side of the switch controlling the current is bridged as shown.

which he must figure out how to install them using the least amount of material and labor consistent with a good installation that will pass inspection.

It should be ascertained how many sockets are to be attached to each outlet, as the code allows only 660 watts to each 2 wire circuit on 40 watts per socket; base plugs are counted as sockets.

After having laid out the number of lights per circuit and the number of circuits, the center of distribution should then be found—if a large house having over 4 circuits, it is advisable to install a panel board that will feed the various circuits; this panel should be installed at a central point.



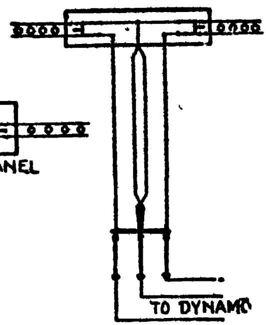


Fig. 5,564.—Three wire convertible, or three wire two wire system; used to advantage where power is supplied from an outside source and brought in through the three wire system. The only difference between the three wire convertible, and the straight three wire system is that the center or neutral wire of the mains and feeders should have a current capacity equal to the other two. *The reason* for this is that it allows the system to be readily changed over to a two wire system for use in connection with a private plant.

Fig. 5,565.—Diagram showing reinforcement of neutral wire necessary to change regular three wire system to two wire system. The capacity of the neutral wire must equal that of the sum of the two other wires.

Panel boards in loft buildings or in any building requiring 8 to 10 circuits to a floor should be distributed one to a floor.

In a building covering a large area it is often advisable to install two panels or centers to a floor, with two sets of feeders. It is advisable to

keep circuit lengths down to 100 feet or less, and the judicious laying out of circuit centers will save many feet of wiring.

The distributing centers or cut out cabinets should be installed near a partition that is so located as to make the running of risers easy, and should be on an inside wall to guard against dampness.

If only one distributing point be used, it should be either in the cellar or attic and risers run to the different floors.

In private houses it is sometimes advisable to install only one panel for the entire house. This is good practice for a three story house not requiring over twelve circuits.

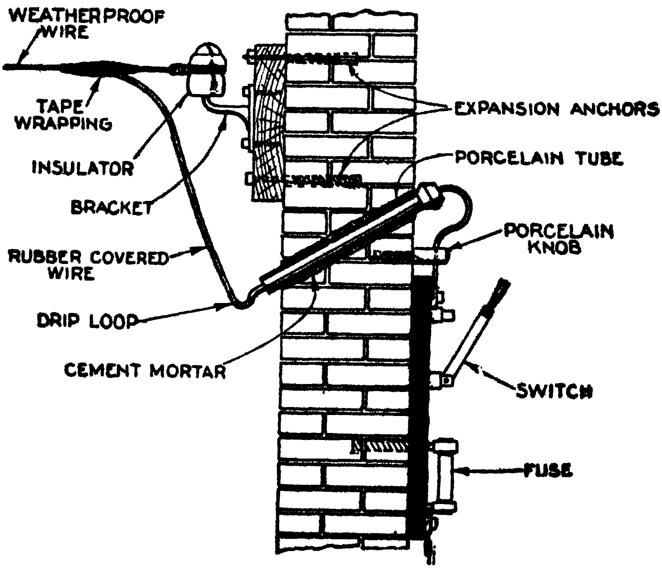


FIG. 5,566.—Tube service entrance for single wire installation.

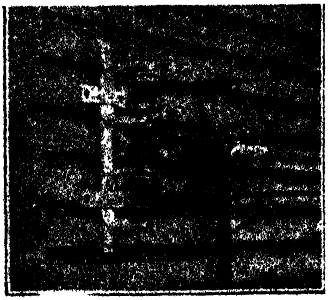
In some cases it is not advisable to install a panel, but to bring the wires down to the cellar, to the meter board where fuse blocks for the various circuits are installed on the meter board.

Service Connections.—By definition a *service* is *that portion of the supply conductors which extends from the street main or*

duct or transformers to the service switch, switches, or switchboard of the building supply.

There are numerous methods of making service entrance into buildings, and they may be classified as

1. Tube;



Figs. 5,567 to 5,569.—Pierce house racks and insulators for service connections showing one, two and three wire installations.

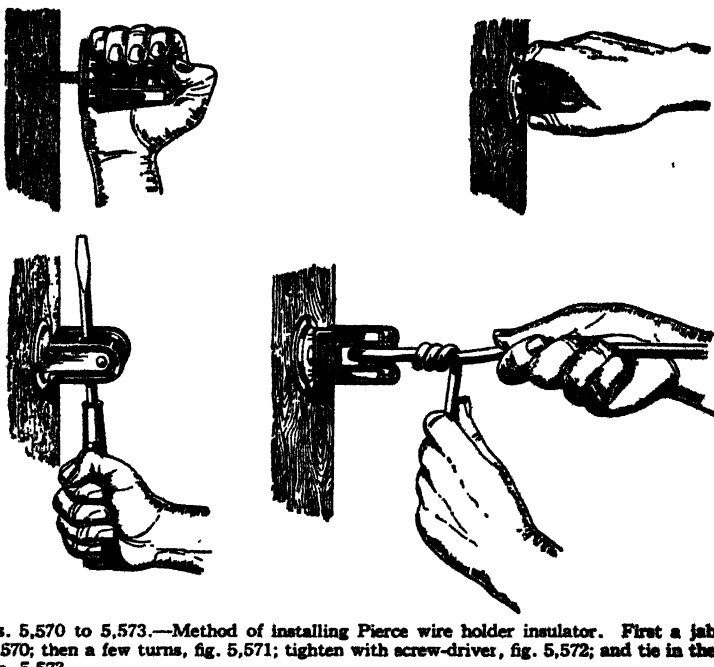
2. Conduit.

   a. Overhead;

   b. Underground.

Fig. 5,566 shows a tube service entrance for a single wire. The essential requirements are

1. Dead end insulator to carry the strain;
2. A connecting loop projecting downward forming a "drip";
3. Extra insulation as porcelain tube where wire passes through building;
4. Porcelain knob to keep wire away from wall and prevent strain on the switch connection;



FIGS. 5,570 to 5,573.—Method of installing Pierce wire holder insulator. First a jab, fig. 5,570; then a few turns, fig. 5,571; tighten with screw-driver, fig. 5,572; and tie in the line, fig. 5,573.

5. Cut out switch.

The conduit overhead service entrance is tne most satisfactory method of bringing in service wires from overhead lines. If it become necessary to install new wires the change is more easily made than with the tube service.

Rigid conduit is used extending from the cut out switch to a point at least eight feet above the ground.

The wires enter the conduit through a fitting called a *service cap*, as shown in fig. 5,574 to protect the wires where they enter the conduit and also to prevent water entering the conduit.

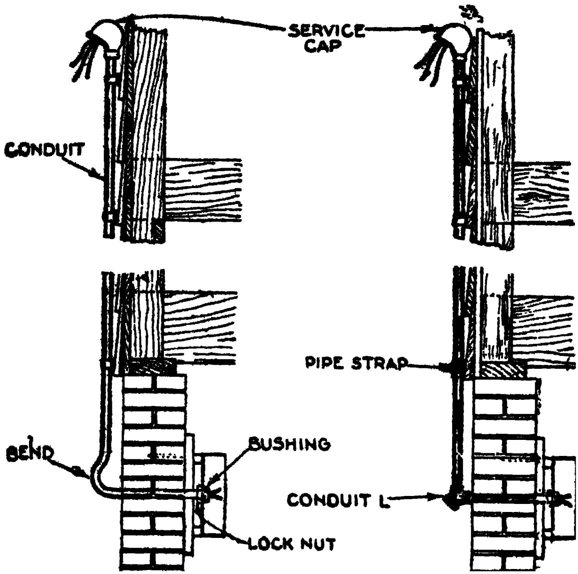


FIG. 5,574.—Service cap as used in overhead conduit service. Note porcelain with holes through which the wires enter.

FIG. 5,575.—Overhead conduit service entrance showing fittings used and connection with the switch box.

To install a conduit service entrance, a hole should be drilled or bored through the wall where the conduit is to pass.

The conduit may then be bent so that the end passing through the wall extends ⅛ inch inside the main line switch cabinet. Instead of bending the conduit, the turns may be made with an approved conduit L fitting (not a common pipe elbow) as shown in fig. 5,575.

The end of the conduit is secured to the switch box by means of a lock. nut and bushing. The locknut is screwed on the conduit before it enters the switch box. The bushing is placed on the end of the conduit inside of the switch box. This bushing is made to protect the wires where they leave the pipe, and should be screwed up tight with a pair of gas or combination pliers. The locknut is then drawn up against the wall of the cabinet until the conduit is held securely in the switch box.

That portion of the conduit which is on the outside of the building is held in place by means of pipe straps, which in turn are fastened with

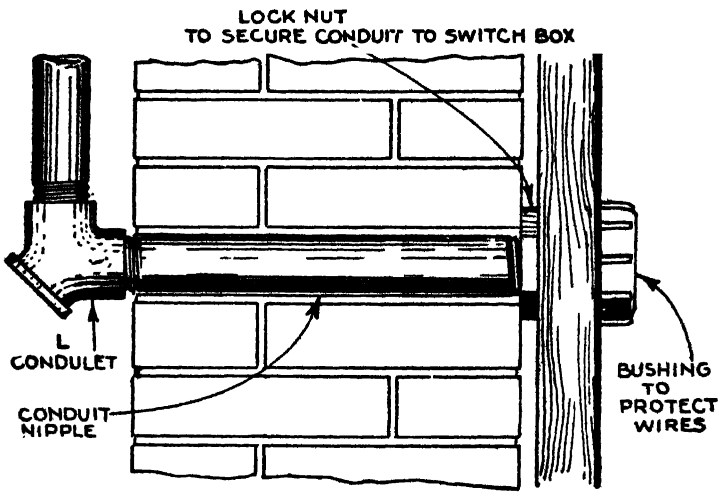


FIG. 5,576.—Fittings used in securing conduit to switch box.

screws. The L condulet must be of the weather proof type. Figs. 5,577 to 5,579 show one type of L condulet. *This fitting is made weather-*proof by placing a rubber gasket between the body of the fitting and the cover.

Underground service entrance consists of a run of conduit extending from the street manhole to the switch box.

Wires encased in a lead sheath are pulled in. These wires must be continuous without a splice. The conduit should be placed deep enough

(at least 30 inches) so that there is little chance of anyone coming into contact with it, while digging the ground for pavement or other such purposes. Care should also be taken to close the openings around the conduit where it passes through the wall. The space between wires and conduit at either end should be sealed to prevent sewer gas entering the building.

Fig. 5,580 shows a typical underground service entrance.

Feeders and Mains.—In making a feeder layout for a large

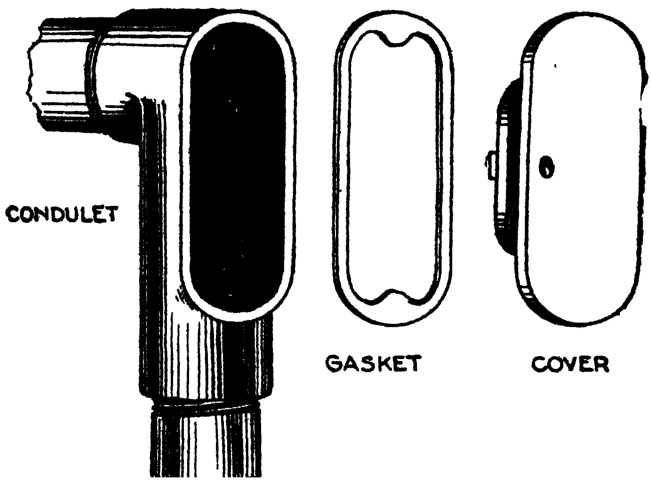


FIG. 5,577.—Weather proof L condulet for making 90° turn. *It is the equivalent of a 90° pipe elbow designed to meet the electrical requirements.*

FIGS. 5,578 and 5,579.—L condulet gasket and cover fastened with screws.

building, a good method is to draw an elevation of the building as in fig. 5,581, and note on each floor the current requirements.

The best plan is to furnish a feeder for every floor, especially in large installations. In smaller installations one or two feeders are sometimes all that are required.

Feeders for motors should be independent of lighting feeders. In calculating sizes, feeders requiring over 2 inch pipe should not be used. It is better to subdivide them, especially if there be many bends or offsets, since two inch pipe is about the limit in size for economical handling.

Feeders should radiate from a distributing panel, having a proper sized switch and fuse for each feeder.

If the system of wiring be such that auxiliary power is taken from a local lighting company, it is a good plan to have each circuit controlled by a double throw switch so that in case of overload, any circuit can be fed from the illuminating company's mains as in fig. 5,562.

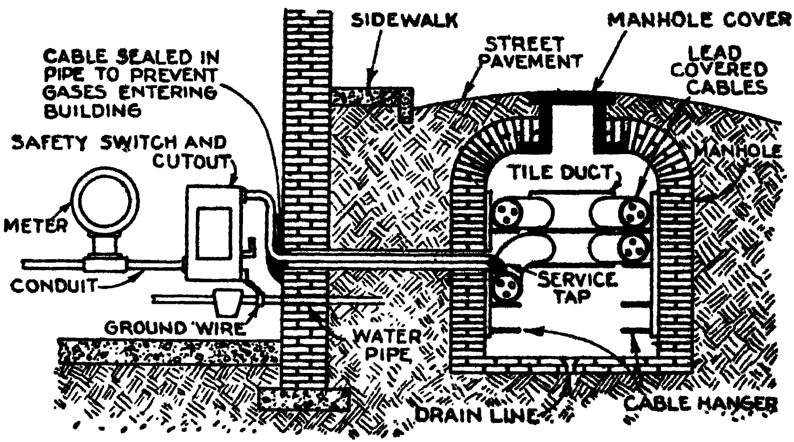


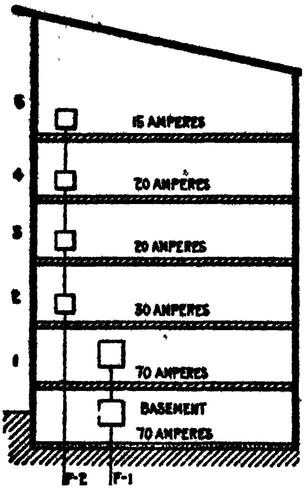
FIG. 5,580.—Underground service entrance.

It is advisable to install feeders and mains in conduit even though the circuit wires be run otherwise. Since the former carry the main supply of current it is important to have them well protected as they usually run up side walls.

The Underwriters make numerous restrictions against open or moulding work on brick walls and require good protection, and this is an additional reason for piping the mains and feeders.

In laying out the branch circuits, it is not good practice to use up the Underwriters' circuit allowance of 660 watts.

If a circuit be wired with the full allowance of lamps, no additions could be made without violating the *Code* requirements.



Locating Outlets.—If concealed wiring is to be installed, the outlets should be marked on the ceilings and walls with a pencil cross at the spot, marking also the location of switches, etc.

If a ceiling outlet is to be placed at the center of the ceiling, it is first located on the floor and then transferred to the ceiling by means of a plumb bob.

Furring Strips.—After locating the outlets a small portion of flooring is removed to find out whether or not there are seven-eighth inch furring strips between the joists and the ceiling plaster.

FIG. 5,581.—Diagram showing current required on each floor of building. A sketch of this kind is useful in laying out the feeder system.

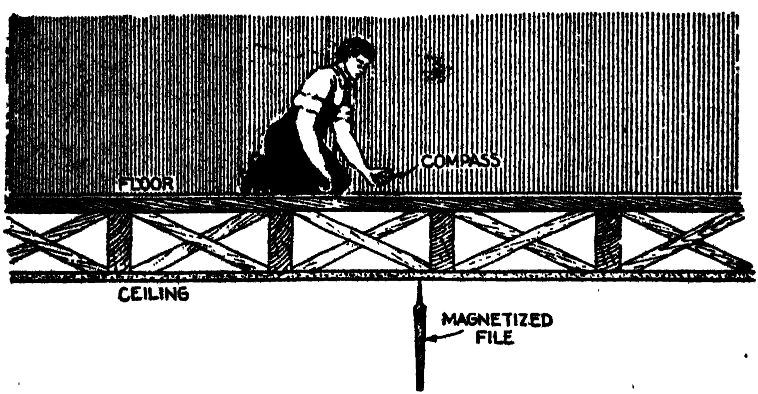


FIG. 5,582.—Method of locating outlet with a compass. A strongly magnetized file is placed at the point selected for outlet, then by exploring on the floor above with a compass, the needle will be agitated when moved directly over the file.

If a house have hot air registers set in the floors, they may be lifted up, instead of taking up flooring. If it be found that there are furring strips, much labor will be saved, as the wires may then be fished from outlet to outlet and little flooring need be removed. All houses, however, are not so built, so in case there be no furring strips it will be necessary to take up the floor and bore a hole in each joist or beam.

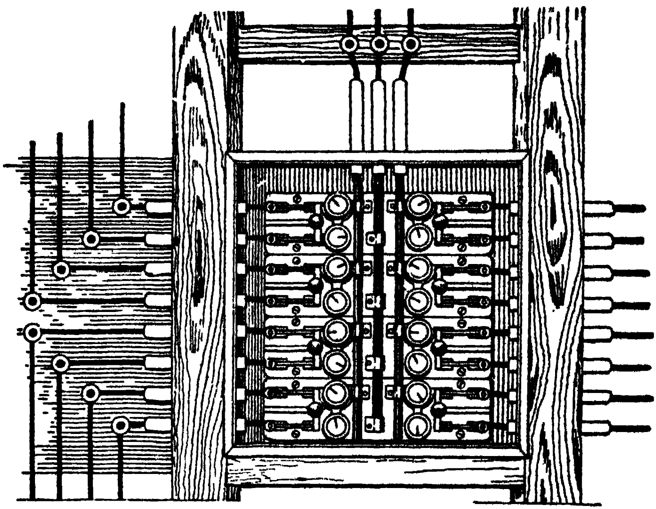


FIG. 5,583.—Installation of wooden cabinet containing fuses and cut out switches for each circuit. The term *cut out box* is usually applied to boxes designed for surface mounting and accommodating only a few circuits, but it is also frequently used to designate the smaller and cheaper forms of boxes used in concealed work. The above box is lined with asbestos or metal. The mains and the branch circuits are led into the box through porcelain tubes. The finished box has a wooden door lined with fireproof insulating material, such as slate or asbestos board, and is finished on the outside to harmonize with the adjacent trim.

Cutting the Outlets.—After locating the centers for the outlets, the plaster must be cut out so that the outlet box will set in.

For this purpose a special tool has been designed; this plaster drill is constructed so that it may be fitted over a gas pipe, the cutters are adjustable so that any size hole may be cut. A bell shaped cup catches any dirt that may be removed so that a neat and clean job is made if a

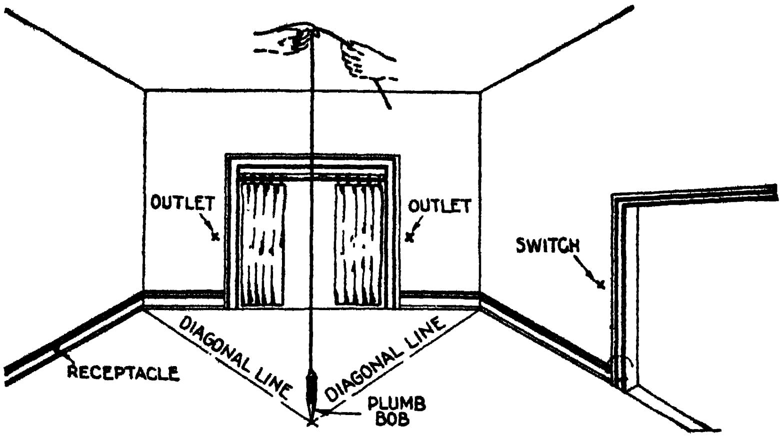


FIG. 5,584.—Marking for outlets and method of locating ceiling outlet on floor and ferring it to the ceiling with plumb bob.

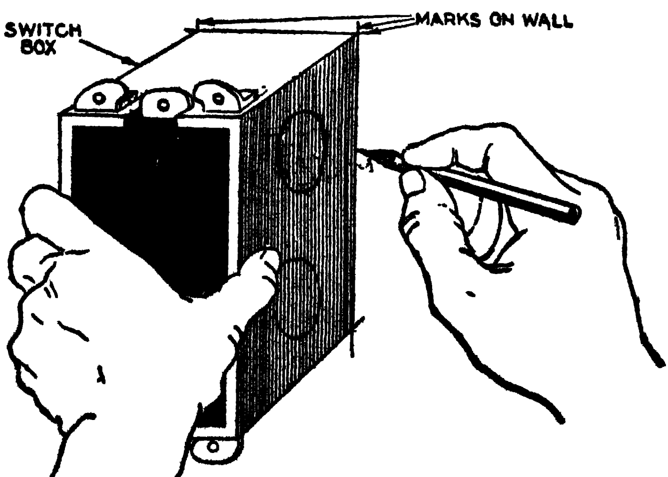
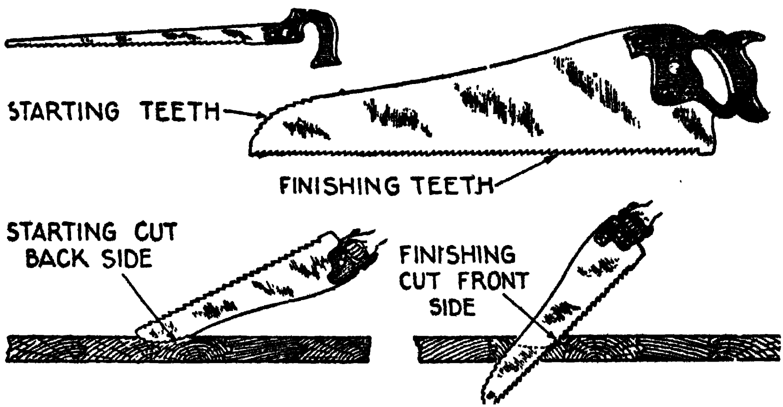


FIG. 5,585.—Marking plaster for fixture outlet box.

drill of this type be used. But if a plaster drill be not obtainable, the outlet box should be traced over with a pencil similarly as in fig: 5,585 and the plaster should be chiseled around this mark with a ¼ inch blade screw driver.

Taking Up Floor.—Various kinds of flooring are to be encountered in wiring houses.

In those built previous to 1875 the floor boards are as wide as 10 to 12″ and are smoothed edged, unlike the present day



FIGS. 5,586 and 5,587.—Floor saws. Fig. 5,586, ordinary compass saw. It should be about 8 to 12 ins. long, very thin blade and tapered to ¼ in. at the end; fig. 5,587, special double edge saw for finished floors.

FIGS. 5,588 and 5,589.—Method of working the double edge saw. Fig. 5,588, starting the cut with back edge; fig. 5,589 finishing cut with front edge.

type of board which has a tongue and groove. This type of flooring is very simple to take up.

If when cutting the outlets, a small hole be bored through the ceiling and the bit pushed up till it comes in contact with the flooring of the room above, and this flooring be also bored, it will show where to take up the flooring to install the wires when they run parallel with the joists. When the wires must run perpendicular to the beams all the flooring must be taken up so that the holes can be bored in the joists through which the wires must pass.

Floor planks are properly removed by driving the nails down with a nail set and lifting up the board.

If double floors be encountered, it will be found very difficult as double floors are constructed of hard wood such as oak, or maple, and must be handled with extreme care and patience. For this type of floor, the tongue is split by inserting a carpenter's floor scraping blade, which is a sheet of steel about $4 \times 6 \times {}^{1}/_{64}''$. These can be purchased at any hardware store at a small sum.

The scraper should be hammered down so that the tongue is split, both sides of the board should be split, so that no difficulty will be experienced when lifting up the board.

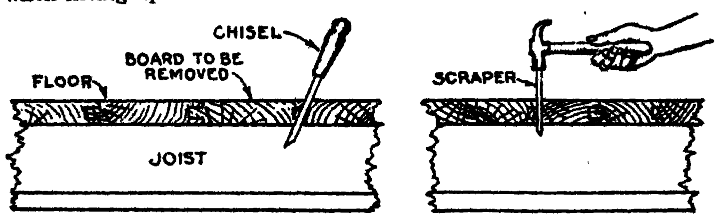


FIG. 5,590 and 5,591.—Two methods of cutting tongue of floor planks. Fig. 5,590, with chisel at angle—this cuts off tongue and also lower lip of adjacent plank; fig. 5,591, with scraper making a vertical cut.

After both sides of the board that is to be removed have been treated as above, a floor chisel should be inserted where the ends of the board meet with another and the board gently raised.

In raising the board, it is better to take time and proceed cautiously, as the finest floors may easily be ruined by having one board split, chipped or marred.

Before the boards are removed, they should be numbered or marked so that they will go back in place without any confusion. They should be placed in a safe place until ready to lay back the floor.

Holes for wires should be bored in the center of the joists so that when laying back the flooring, the nails will not penetrate the metal sheath and short circuit or ground the wires.

Cutting Pockets.—The center of each pocket is indicated by

the small hole which was bored through the flooring when cutting the ceiling outlets.

In opening a pocket ¼ in. holes are bored to insert a keyhole saw through

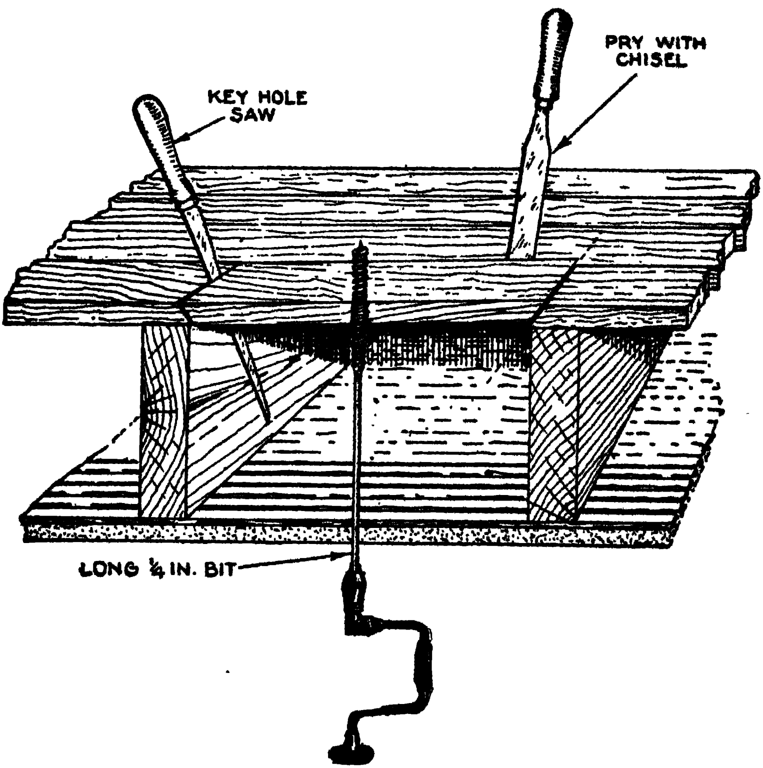


Fig. 5,592.—Sectional view showing method of cutting a pocket or opening in floor for the insertion of wires.

the joint between two boards at each end of the pocket, and as near the beams as possible, then the board is cut at an angle as indicated in fig. 5,592.

Next saw the tongue of the matched board on each side and pry up the boards with a chisel. Having taken up the boards, nail a cleat

on the side of each joist as in fig. 5,593 so that when the floor is laid back there will be a good support.

A base board is next installed as in fig. 5,593 to give a secure hold for the

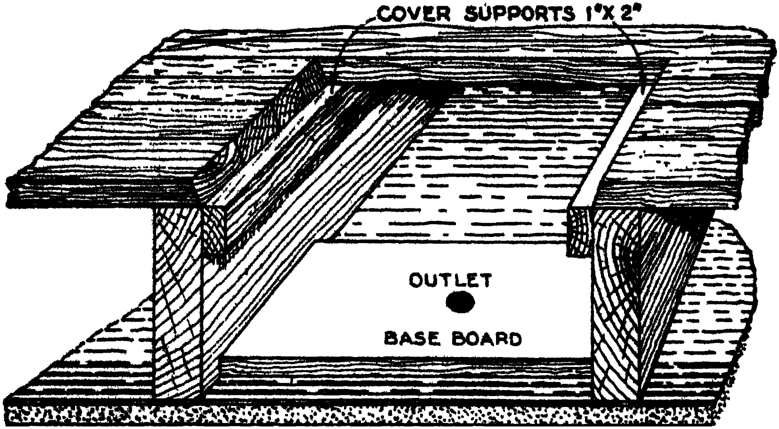


FIG. 5,593.—View of outlet pocket showing base board, and cover supports in position.

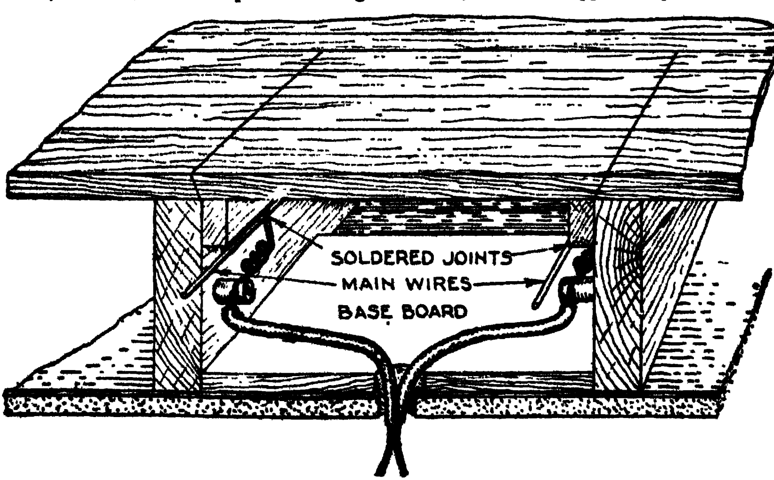
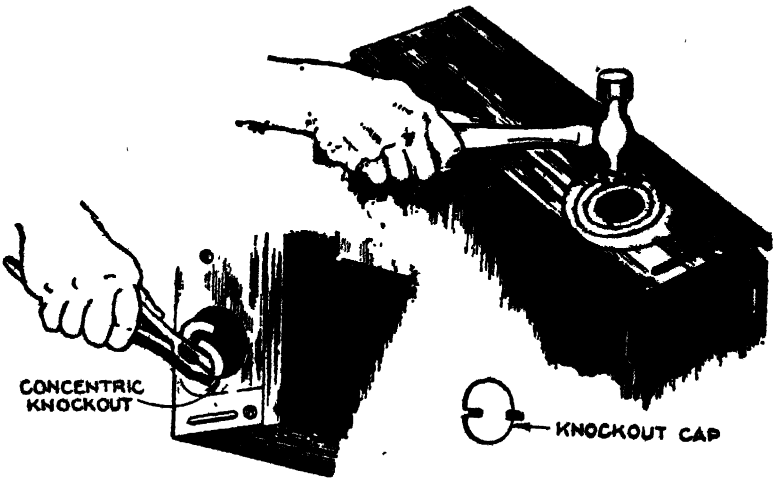


FIG. 5,594.—View of completed pocket and ceiling outlet showing method of bringing out the wires.

screws used in fastening the fixtures. Two holes are then bored diagonally with an $^{11}/_{16}$ inch bit, inserting the bit in the small hole bored in the ceiling as in fig. 5,592. The outlet wires are then tied around the knobs, the upper ends being bared and tapped on to the main wire. A piece of loom is slipped on each outlet wire after which it is thrust through the outlet as in fig. 5,594.



FIGS. 5,595 to 5,597.—Methods of removing knockouts and detail of knockout cap. Knockouts are ½ inch, ¾ inch and 1 inch in size for the accommodation of different sizes of pipes There are also concentric knockouts which make it possible to accommodate any one of several sizes of conduit. Not more than the necessary number of knockouts should be uncovered. In case some that are not used are removed, the holes must be closed. This can be done by inserting a knockout cap.

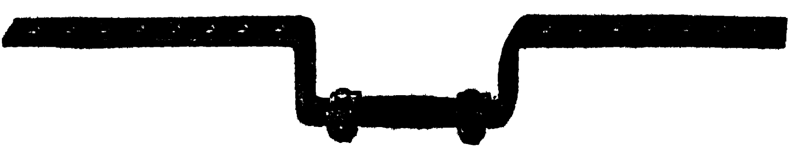


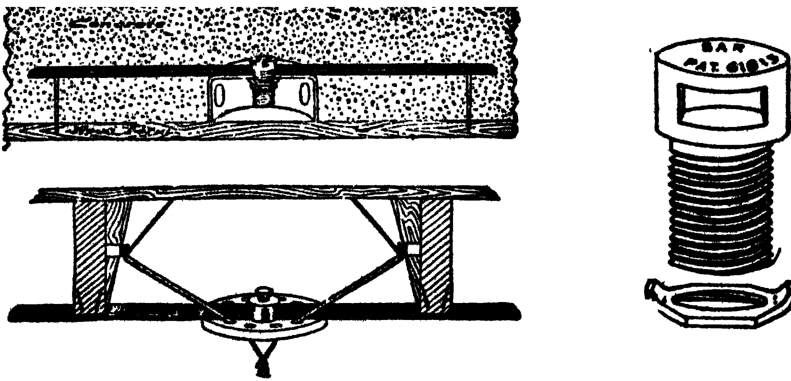
FIG. 5,598.—Austin universal box cleat used chiefly for side wall construction; can also be used on ceiling work. By nailing it across the front of joists a flush position for the box is obtained.

Installing Outlet Boxes.—To comply with the *Code* a box called an outlet box must be installed at each outlet.

Outlet boxes for loom wire are shallow iron boxes about ½ inch deep and made in two diameters, 3½ inch and 4 inch.

The base of the smaller box ordinarily has one knockout for a ½ inch pipe at its center. This is to allow a gas pipe to pass into the same outlet, if necessary. There are also six knockouts for loom to pass into the outlet.

The larger box is similar to the 3½ inch size, but there are eight knockouts for loom. No knockouts are placed in the side wall of either box.



Figs. 5,599 to 5,602.—Application of Austin straight bar hanger and view of stud and lock-nut. All four knockouts are accessible in standard outlet boxes; especially suited to loom box, all eight knockouts can be used.

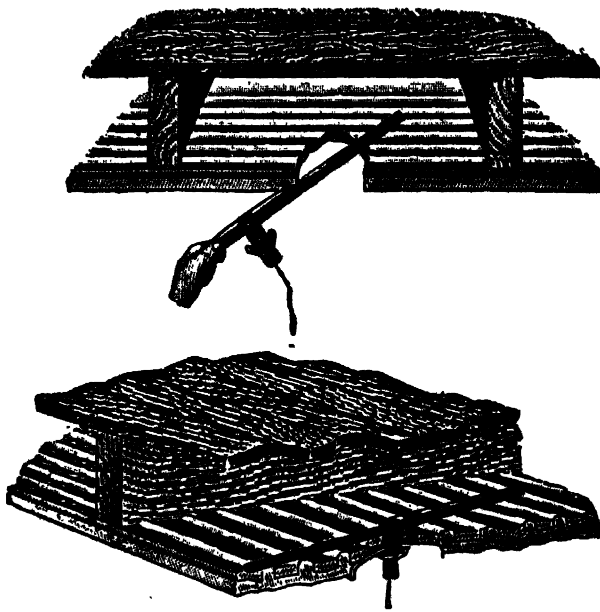
One knockout is removed for each wire, but no more should be removed than are necessary. If more be removed than are used, the box will be condemned by the inspector, unless the holes be plugged with metal.

Some boxes are equipped with clamps for fastening the loom, others are plain; and some other means of holding the loom in place is needed.

Each box has small holes in the base for fastening fixture studs and for fastening the box to a hanger. Some cities require deep outlet boxes for certain light outlets, such as for bracket lights. These boxes are 3 and

4 inches in size and about 1½ inches deep. They are made in several shapes, such as round, octagonal and square.

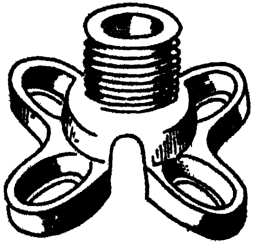
For light outlets, the round and octagonal boxes seem to be preferred. This is probably due to the fact that the covers or trims for the round box also fit the octagonal, while the square box requires a different cover.



FIGS. 5,603 and 5,604.—Austin "Economy" old work hanger. *Application:* The plaster is opened only large enough to permit the stud to pass through. The stud is then slipped up the end of the bar as shown and the assembly slipped through the hole. When the box is in a horizontal position, the wire leader is drawn through the stud. This slides the bar into position and centers the stud on the bar. The outlet box is fastened to the stud with a locknut and secured tightly in place.

FIG. 5,605.—Adapting ring.

The base and the walls contain knockouts ranging from the loom size to the ¾ inch pipe size. Outlet boxes like loom boxes are punched for fastening fixture studs, and also for fastening to outlet box hangers.



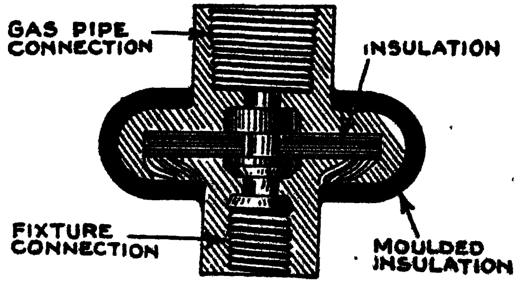


FIG. 5,606.—Fixture stud for supporting fixtures to outlet boxes.

FIG. 5,607.—Insulating joint. This fitting is used for fixture work. Insulating joint should be tested before being used.

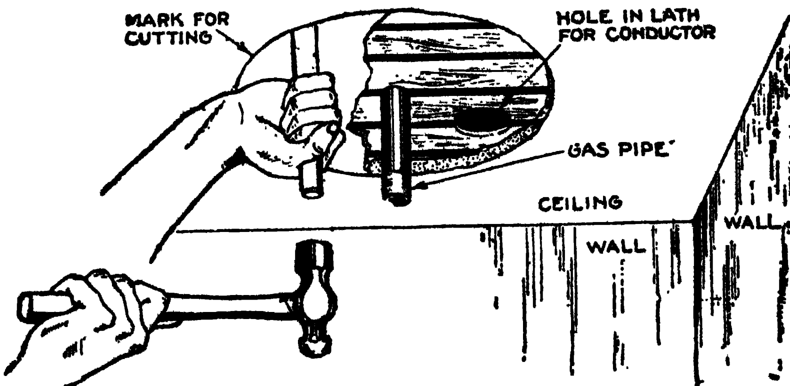


FIG. 5,608.—*Method of installing outlet box. 1.* Cut out plaster to circle located as in fig. 5,584. After lath is exposed, remove a small piece of lath, or bore holes in lath for the flexible conductor entrance. These holes should register with the two knockouts previously removed from the box for the entrance of the conductors. The size of the cut out plaster is exaggerated for clearness.

Fig. 5,582 shows the method of locating an outlet box.

After the plaster has been removed, the outlet box should be set in, so that it will fit snugly.

The *Code* requires that the lower edge of all outlet boxes should not be set back in plaster any farther than ¼ inch.

The box should be fitted to the hole in the plaster, and the lath should then be marked and notched out with a jack knife to allow the cable to

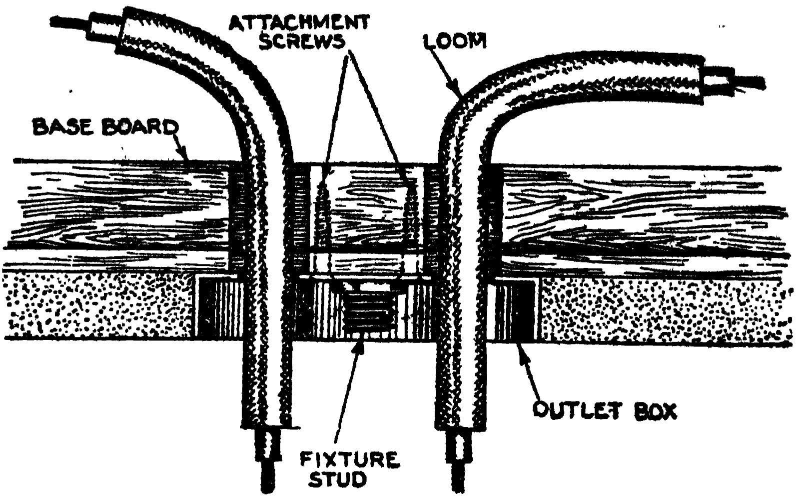


Fig. 5,609.—*Method of installing outlet box.* **2.** Place box in position so that the holes from which knockouts were removed register with the holes cut out of lath. Secure box to cleat with screws having previously attached the fixture stud as shown.

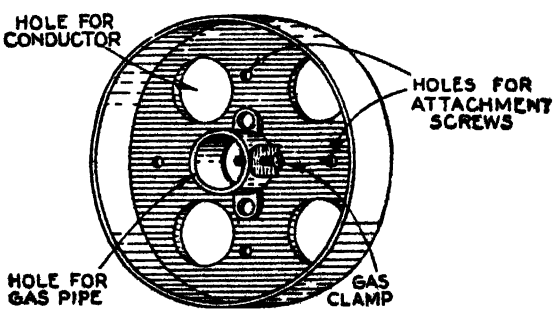
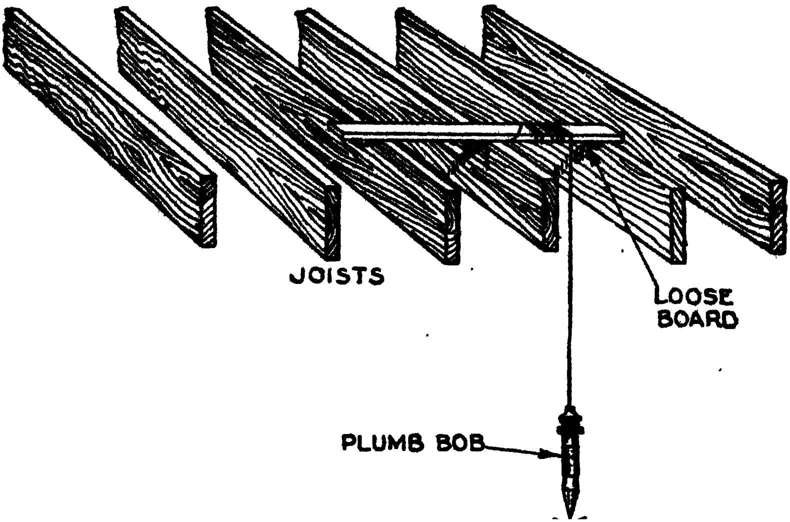
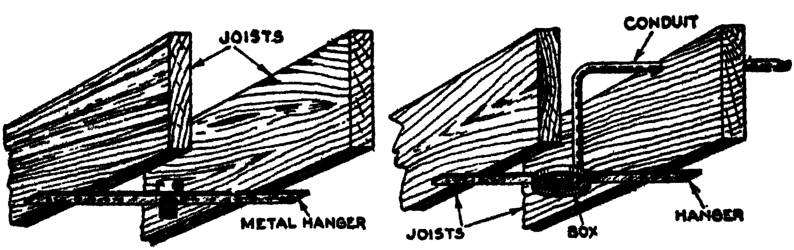


Fig. 5,610.—View of outlet box with gas clamp attached, the fitting used when installing box at gas outlet.

properly pass through into the box. Securing outlet boxes to laths is not allowed as this is not considered as a support, and in time will loosen up the plaster.





FIGS. 5,611 to 5,613.—Method of installing an outlet box in unfinished frame building. Having marked the position of the fixture outlet on the floor as in fig. 5,611, remove necessary knockouts from box and attach fixture stud. Nail a metal adjustable box hanger (if available) to the under side of joists, as in fig. 5,612, so that center of hanger will come in correct position. Attach box to hanger, as in fig. 5,613. If the box hanger have a fixture stud, none is required in the box, but the center knockout must be removed, and the box attached to hanger with locknut on the hanger fixture stud. Pass through box the flexible conductors or attach conduit as in fig. 5.613.

The only places where a board is not required is where an outlet happens to be located on a beam, joist or stud. Side lights can be located on upright studs which are the best supports to be obtained. It is not always possible to locate outlets on joists, and still have the outlet in the center, for this reason outlet boards should be installed. These should be very carefully installed so as not to mar the ceiling.

Where the outlet is to be made to existing gas pipe outlets combination boxes should be used. No board is required, and the box must be securely fastened to the gas pipe.

Where the plaster is broken it should be repaired with plaster of Paris.

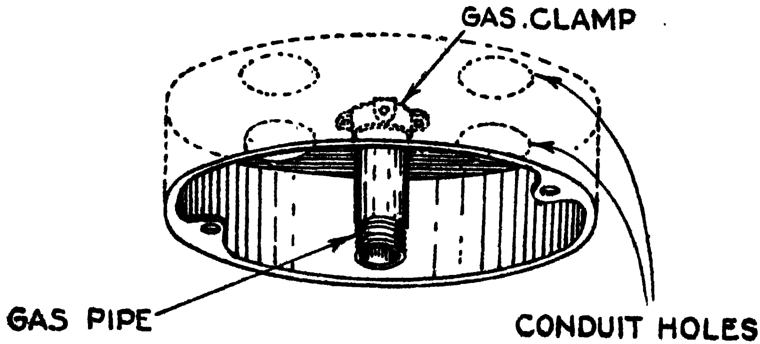


FIG. 5,614.—Outlet box installed at gas outlet.

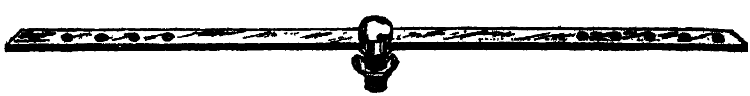
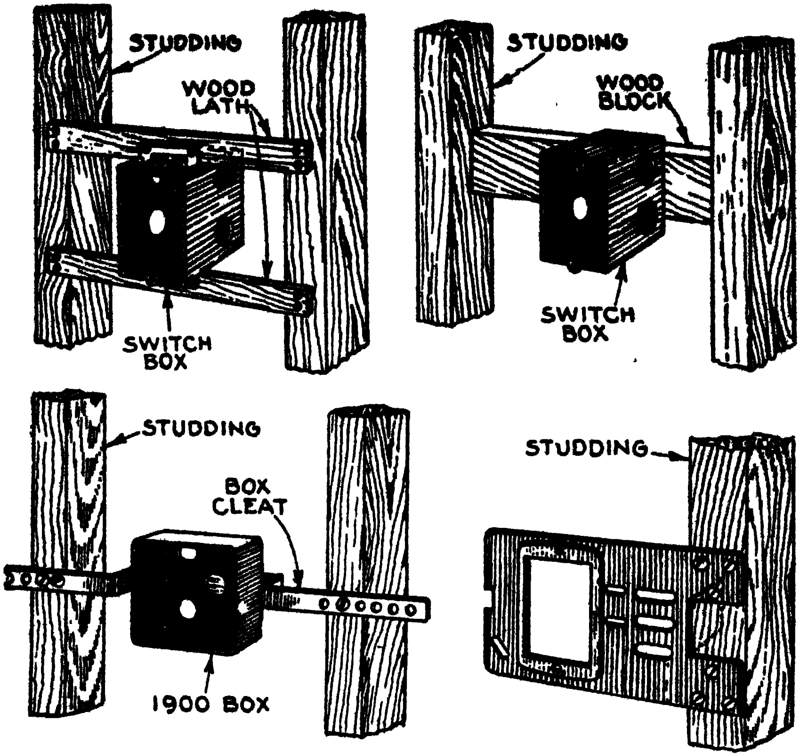


FIG. 5,615.—Austin straight bar hanger and stud. The stud is slotted allowing free movement along the bar, yet may be easily tightened by the locknut in any selected place, making it possible to set box at desired spot although conduit may bear a little off length.

There is a multiplicity of outlet box types designed to meet the varied requirements.

Cutting Out Switch Box Outlets.—This is a difficult operation and must be performed carefully.

After having first ascertained that it is possible to drop down the partition, 54 inches is measured up from the floor, the



FIGS. 5,616 to 5,619.—Methods of installing switch box in unfinished wall. Fig. 5,616 using wooden laths; fig. 5,617 wooden block at back of box; fig. 5,618 metal box cleat; fig. 5,619 combination switch cover.

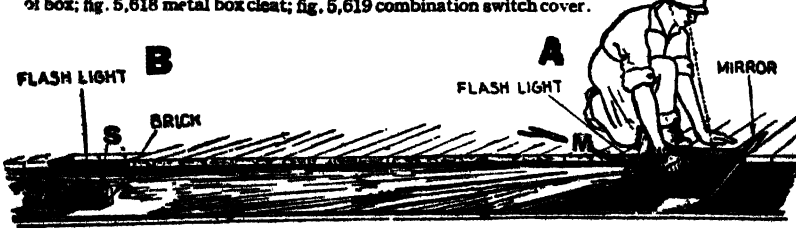
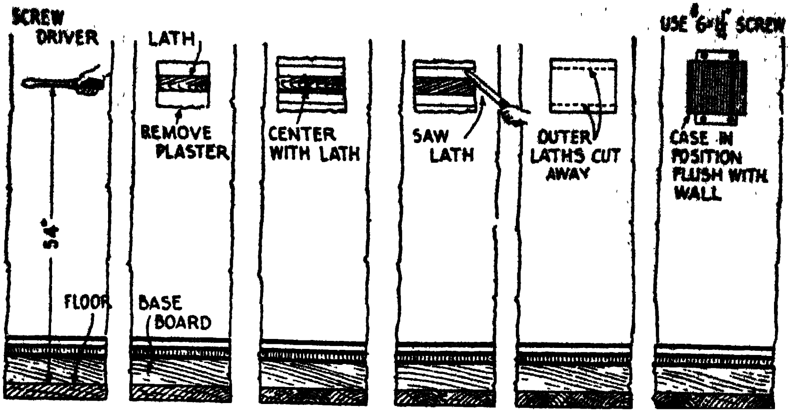
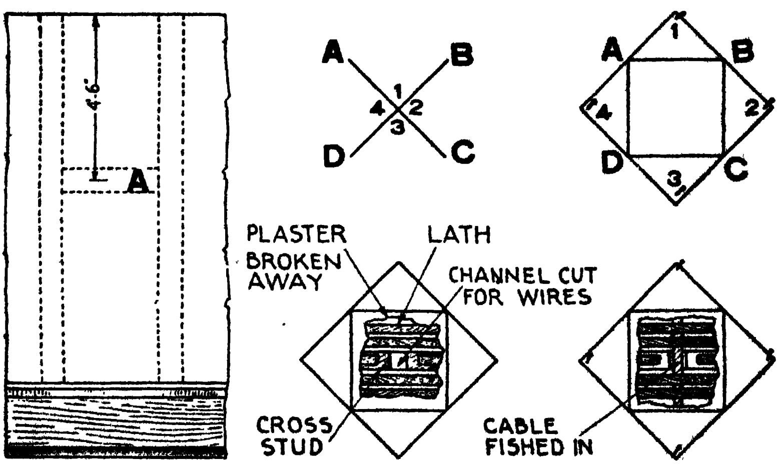


FIG. 5,620.—Exploring with flash light and mirror. If there be only one pocket cut, place mirror and hold flash light as at A. In case there be a second pocket as at B, the flash light may be placed at S, supported on a brick or other object.



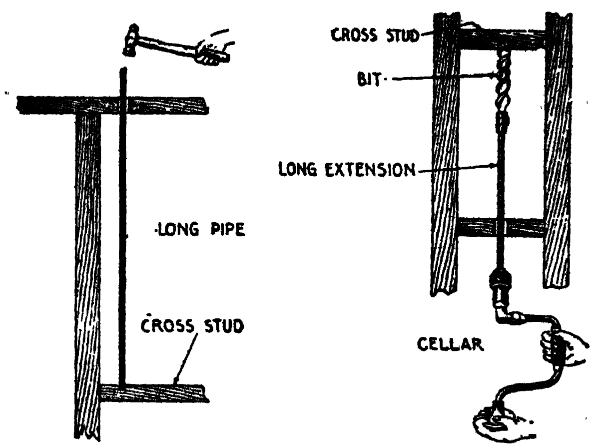
FIGS. 5,621 to 5,626.—Method of cutting out wall case outlet as described in the accompanying text.



FIGS. 5,627 to 5,631.—Method of passing by cross stud in partition when plaster must be cut. Locate cross stud as in fig. 5,627, 4½ ft. below ceiling. With a sharp knife cut wall paper along two diagonals AC, and BD. Thoroughly moisten paper with a sponge. Peel back the ends 1.2 3.4. to the position shown in fig 5,629 and fasten with pins. Cut out

plaster is punctured with a screw driver. If the screw driver go between the lath, another hole should be punctured, and so on until the plaster has been broken away and shows a whole lath; now take the wall case and center the lath with the center of the wall case, with a pencil, run over the outer edges of the wall case.

Now with a hammer and screw driver, carefully chisel out the plaster on the pencil lines. After the plaster has been removed, with a fine key hole saw,



Figs. 5,633 and 5,634.—Two methods of passing by cross stud in partition: 1, by inserting from above a long pipe and breaking stud by hammering; 2, by boring up from cellar with brace and bit having a long extension.

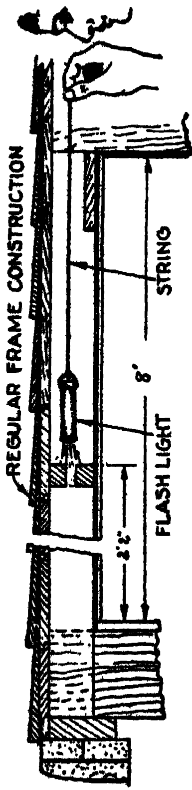
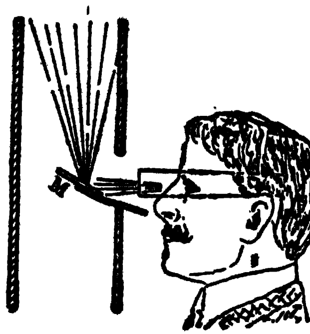


Fig. 5,632.—Exploring with flash light in side wall of house.

Figs. 5,627 to 5,631.—*Text continued.*

the plaster in the square thus opened and cut a channel in the cross stud as in fig. 5,630 Fish in the cable as in fig. 5,631, replaster and fold back wall paper, pasting it to cover the square just plastered.



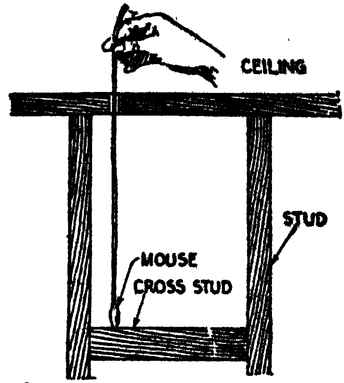
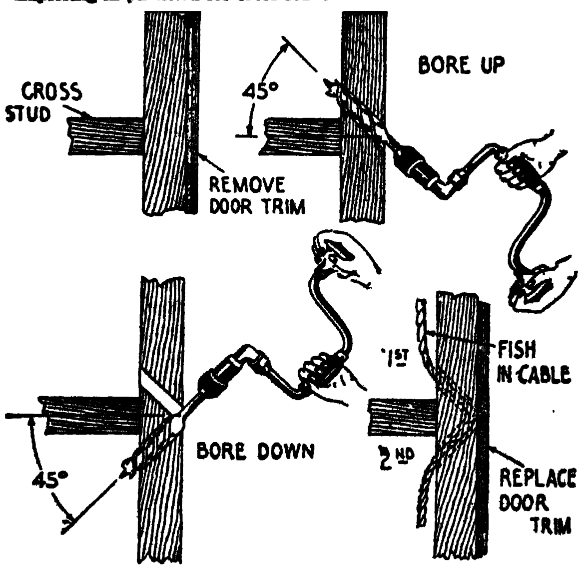


FIG. 5,635.—Device for examining partition interiors. A pocket flash lamp and a little mirror are the only apparatus required to inspect the interior of a wall or partition which would ordinarily be inaccessible. For fishing wires, retrieving cable and inspecting finished work, the lamp and mirror will be found most useful.

FIG. 5,636.—Exploring in partition for cross stud.



FIGS. 5,637 to 5,640.—Method of passing by cross stud in partition when wires are run to a door.

carefully cut away the center whole lath, after this has been cut away, the other lath should be trimmed with a sharp jack knife so that the box fits snugly. The ears of the box should be adjusted so that the box fits just flush with the finished plaster. Now screw box to lath with 1¼ inch No. 6 wood screws, any larger than these will crack the lath.

Obstructions in Partitions.—In the older houses constructed when builders had some regard for strength, partitions were reinforced with cross studs so that it is impossible to get by them.

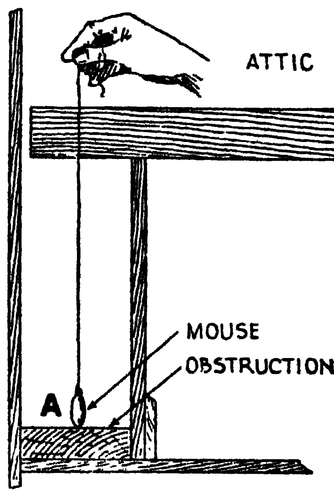
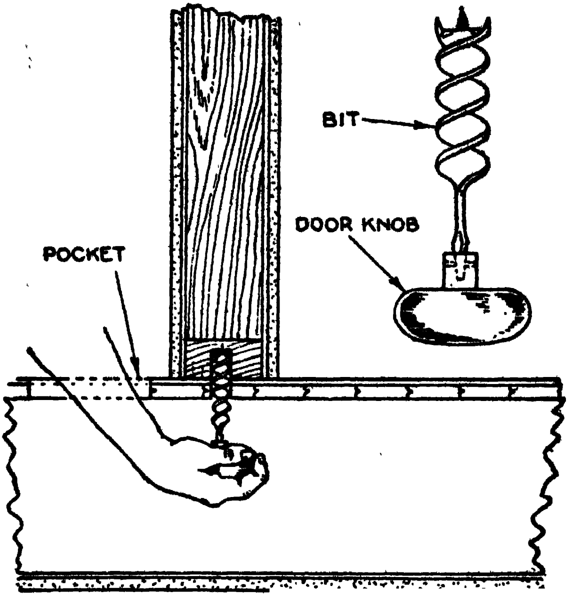


FIG. 5,641.—Exploring between inner and outer walls with mouse. At A, an obstruction is encountered. This must be cut or bored to permit wires to pass. It may be reached by removing the base board, or may be bored from above with a multi-extension bit.

When a cross stud is encountered, the switch outlet may be located above the stud, the standard height being 54 inches above the floor.

Before attempting to drop down a partition it should first be ascertained whether or not a cross stud or concrete, mineral wool, brick or rubbish filling, is in the partition. A hole is drilled in the top header of the partition and a string with a lead weight lowered, if the weight reach the floor (this can be ascertained by sound) the partition is clear.



FIGS. 5,642 and 5,643.—Boring through partition shoe with "door knob bit" so as not to disturb base board when wires are to be run from floor pocket into partition. Fig. 5,643, detail of door knob bit.

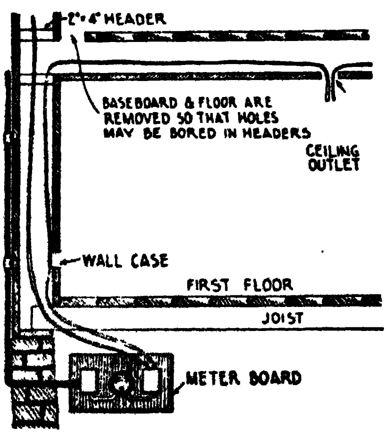
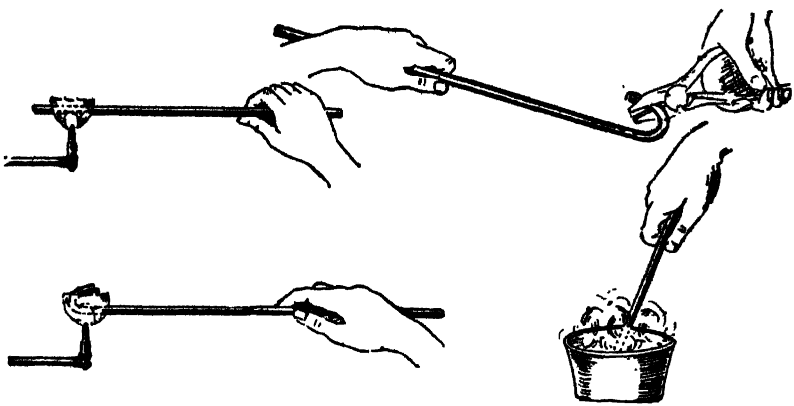


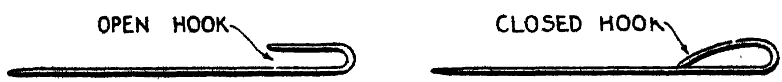
FIG. 5,644.—Method of dropping down a partition that has headers, also showing method of bringing circuits down to meter.

Dropping Wires Down Outer Walls.—First a hole should be bored in the header and the mouse lowered until it reaches the cellar, or hits an obstruction.

Usually obstructions are encountered as fire stops are placed at each floor to prevent the enclosed space acting as a flue in case of fire. These stops usually consist of 2×4 strips or brick. To reach them the base-board must be removed. This is easily pried off with a floor chisel, some-



Figs. 5,645 to 5,648.—Method of making a snake. Hold wire in flame till cherry red (fig. 5,645) bend to shape (fig. 5,646); heat again (fig. 5,647), and submerge end in cold water while cherry red (fig. 5,648).



Figs. 5,649 and 5,650.—Open and closed snake hooks. ***The open hook*** is used in hooking one snake to another. ***The closed hook*** is used for fishing.

times it is necessary to set in the nails with a nail set. If walls be of brick, the entire distance from attic to cellar may be fished with a steel fish or snake wire, as the laths are attached to a $\frac{7}{8}$ strip which is nailed to the brick.

Fishing.—This is a method of running wires through walls, floors and ducts by the aid of another wire called a ***snake*** or fish

wire attached to the conductors, threaded and drawn through in advance.

Snake or fish wires are made of the best steel and tempered in oil. All snakes should have a hook bent at each end, and to do this the wire must first be annealed.

The proper method of annealing is to hold the end of the snake in the flame of a torch until it becomes cherry red, then bend into shape, heat again to cherry red color and quickly insert the heated end in a pail of water; this hardens the wire, so that the hook will not pull apart.

Fig. 5,651.—Method of taping end of snake.

Fig. 5,652.—Method of attaching wires to snake for pulling.

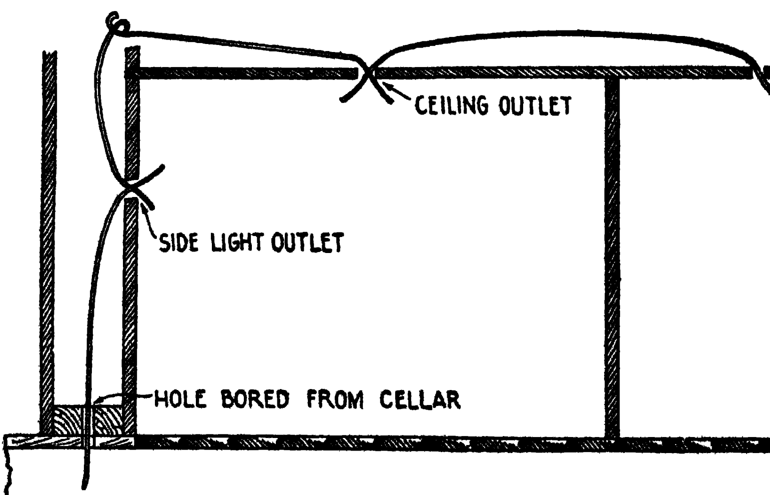


Fig. 5,653.—Fishing from outlet to outlet.

Snake wire may be obtained in various shapes but the type best adapted for house work is ⅛ inch wide, $^1/_{16}$ inch thick.

The proper way to attach the wires to be pulled into the snake is to just loop them through the hook of the snake and fold them over with pliers.

If wires are to be pulled through a long run, they should be taped.

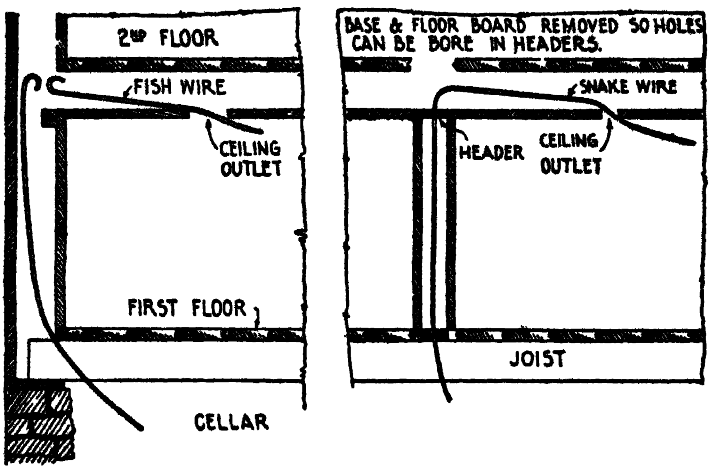


FIG. 5,654.—Method of fishing in wires without removing floors or base board. The fish or snake wire is pushed up from cellar and hooked as shown. This method is only possible when there are no headers.

FIG. 5,655.—Method of fishing in wires through headers.

In fishing in a house constructed with furring strips between the joists and ceilings there will be plenty of room to draw through the loom or cable.

Furring strips in old houses having single floors will be found to run parallel with the floor boards.

After having cut the outlet as just described, a steel wire or snake is inserted into the hole so that it may be pushed into the space made by the furring strip, having inserted the end of the snake, it is gently pushed as

far as desired; if the snake encounter an obstruction, it may be caught against a piece of plaster or become twisted.

With a little practice a snake may be fished over 50 ft. with ease, having reached the outlet, another snake or piece of wire is pushed up into the hole at the outlet and the snake is *hooked*, and then gently drawn through the outlet; the wires are then attached and pulled through. If a man be at each end considerable labor will be saved.

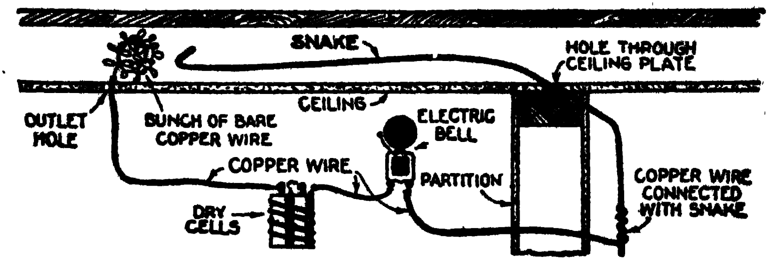
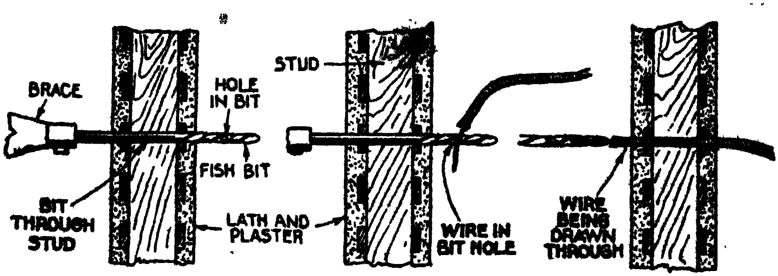


FIG. 5,656.—Method of fishing with snake and electric bell.



FIGS. 5,657 to 5,659.—Method of using steel fish bit. After boring through as in fig. 5,657, thread end of wire through hole in bit (fig. 5,658), and withdraw bit bringing with it the wire that is to be passed through the bored hole as in fig. 5,659.

When pulling through the wires it is also necessary that some one be at each end so that one may feed the wires in and the other will pull them out.

The wires should be gently pulled so no damage will be done to the plastered ceiling.

If, in pulling the snake, the wires get stuck, the snake and the wires should be pulled back and forth as most likely the wires are caught against a plaster clinker. This operation will break off clinkers.

Sometimes a whole house may be fished without taking up any floors. but it may be necessary to take off base boards and flooring to drop down to the meter board or switch outlets.

Sometimes it is necessary to use two snakes on long runs and hook them underneath the ceiling.

In this case the ends of the snakes should be connected to a bell and battery so the bell will ring when the ends touch each other.

Switches for Lighting Installation.—Plug fuse switches are only approved for use on voltages up to 125 volts and to stand a load of 30 amperes.

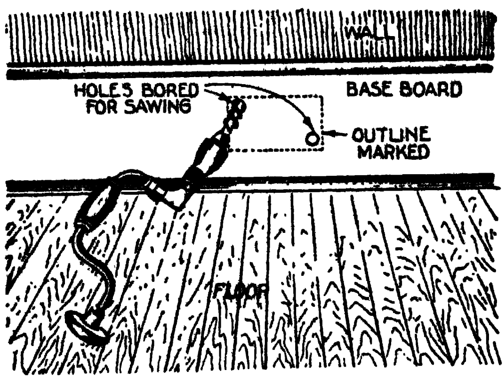


FIG. 5,660.—Installing switch box in base board. 1, mark outline of box on base board; 2, bore two holes as shown to start saw; 3, saw to outline; 4, clear opening to bring box flush; 5, install box in opening after removing suitable knockouts.

In the case of a fair size residence a 30 ampere switch of the plug type could probably be used (note types of switches optional with local central stations).

In the case of a large installation having a load exceeding 30 amperes, cartridge fuse switches and cut outs must be used.

These are designed for pressures up to 600 volts.

Cut out boxes usually have ½ in. knockouts; if a larger size conduit be used, these knockouts must be enlarged by reaming unless boxes with

larger size knockouts be obtained. The conduit is secured to the box by two lock nuts and a bushing.

Wires leaving the cut out box should pass through porcelain insulators or bushings.

The box should be secured to the board by means of ¾" wood screws.

The switch or cut out should be secured in the box by means of holes drilled or punched through the box, wood screws passing through the cut out box and screwed into the wood meter board will securely hold any cut out or switch.

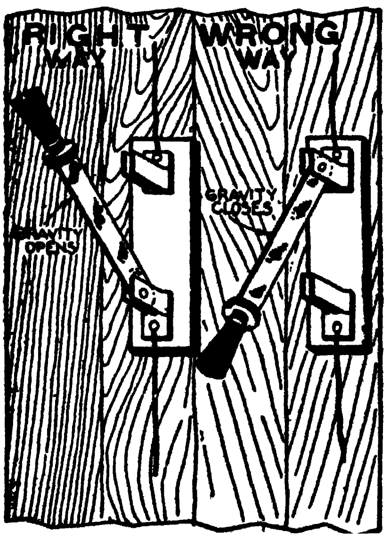


FIG. 5,661.—*Right* and *wrong* way of installing knife switches. They should always be installed so that gravity tends to open them, otherwise when the hinges become worn, the switch might close.

Installation of Knife Switches.—When installed in a vertical position, the switch should be so placed that gravity will tend to open it.

Where a three wire switch is used, the middle or neutral fuse clip must

be made solid so that no fuse may be installed in the center clip (this is for lighting installations on a single phase or a *d.c.* system).

Installing Flush Switches and Receptacles in Wall Cases.—Care should be taken that the switch fits flush with the edge of the plaster. In order for the switch to fit flush, the case should fit flush, otherwise it will be necessary to insert small washers under the switch ears.

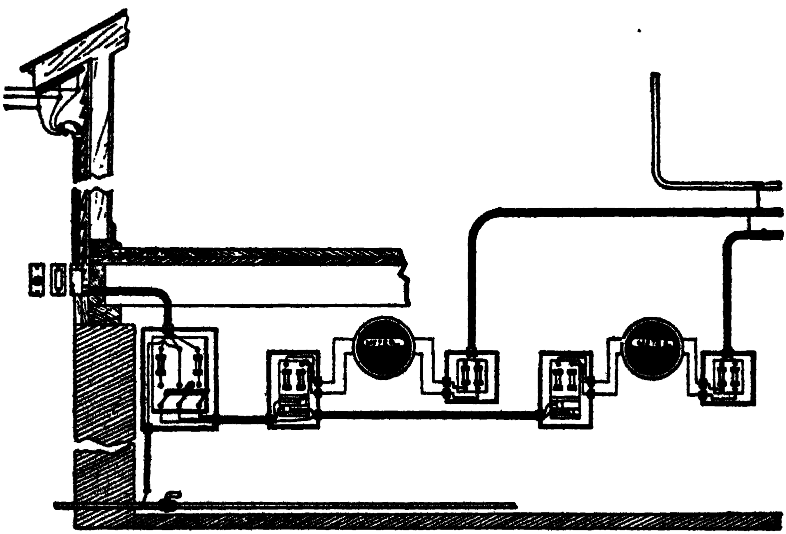


FIG. 5,662.—Two family house meter board arrangement as used throughout Connecticut; note method of service pipe and meter loop arrangement.

Switch plates will not fit properly unless the switch be flush; if the switch be not flush, the plate will buckle and bend in the center.

Perfect fitting switch plates give an artistic and workmanlike appearance to any installation.

Meter Boards.—A meter board should be constructed of

seven-eighths inch soft wood (pine) of sufficient size to accommodate the meter and cut-out boxes.

Secure the board against the foundation wall of the building. Paint board two coats of black asphaltum or other insulating paint. Do not nail boards to foundation wall unless there be an air space back of it. The use of 2×4 studs makes a secure board. For one single meter, a board 24×18 is amply large with room to spare for future additions. The main switch is mounted on the left side of the board. All modern meters feed the left for mains, and feed out to the right for house cut outs. Do not place a meter board any higher than 7 ft., or lower than 4½ ft.

Replacing Floors and Trim.—In replacing floors, small finishing nails should be used; these are inconspicuous and will not split the wood while being driven.

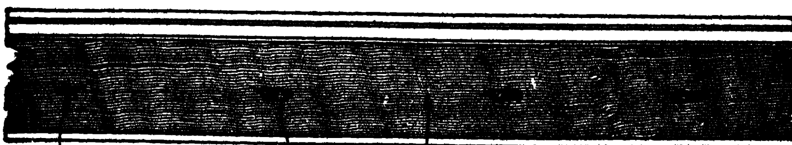


FIG. 5,663.—Appearance of a varnished base board after nails are driven out. The proper way is to leave nails in the board, cutting them off close with cutting pliers.

When replacing base boards and other finished trim that has been pried off do not attempt to drive back the nails, but cut them off with cutting pliers, as driving the nails back will knock off large chips from the trim.

After the nails have been cut off, the head of the nail should be set in with a nail set and a new nail driven in the same hole.

Hard wood floors and trim should be gone over with floor wax to remove all scratches and mars.

Drop Cords.—Where the wires enter a socket, rosette, or an outlet box, they should be relieved of any strain by making an Underwriter's knot so that the weight of the socket, shade and lamp will not be on the joint.

Square or granny knots are not approved, sockets may be obtained with strain relief devices attached.

Stripping Drop Cord.—With a sharp knife cut around the outer braid

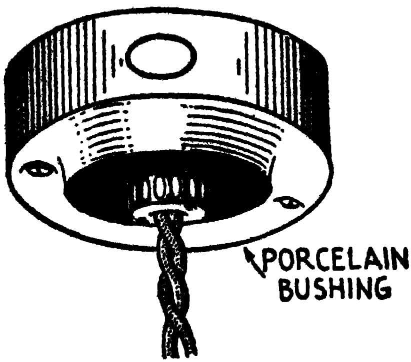
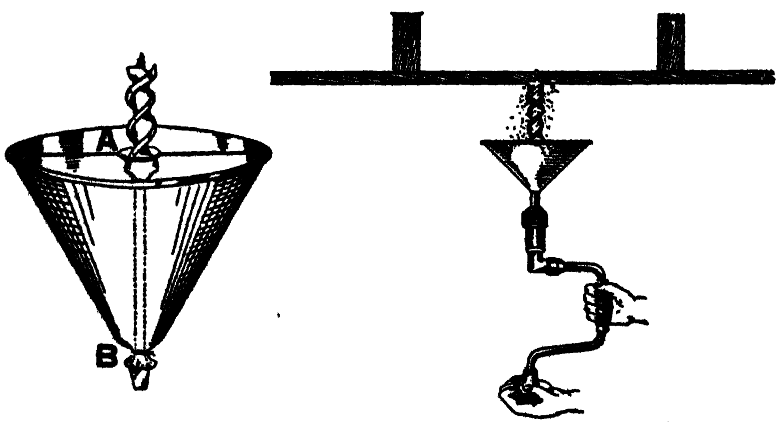


FIG. 5,664.—Drop cord fixture leaving conduit outlet box cover. A porcelain bushin be used with all metal covers.



FIGS. 5,665 and 5,666.—Cone dirt catcher for bit and application in boring ceiling outlets. *It consists of* a suitable size cone, made of stiff cardboard and provided with a guide A, to hold it central with the bit. Attached to the lower end is a cloth tube B, which is fastened with a string to the shank. Fig. 5,666 shows the cone in use.

just deep enough to cut the braid and re-enforced rubber covering. Then cut a slit parallel with the cord just deep enough to cut only the outer braid. Remove outer braid and with each hand, pull on each wire and re-enforced rubber braid will fall away. About 2 ins. is sufficient for sockets, and rosettes; 6 ins. to be allowed where the cord is to be spliced to other wires such as in outlet boxes, etc.

Uses of Drop Cord.—For inside of residences, re-enforced cotton cord can be used with a light outer braid. For factories, the heavy type should be used. For cellars, the slicked or weather proof type should be used. For bakeries or places where wires are subjected to a great heat or where the cord is attached to heating appliances, regular asbestos heating cord must be used.

For auto garages, extra heavy marine deck cable should be used, or the same encased in a specially wound metallic sheath.

For show windows B. X. drop cord must be used.

Clusters of more than one light must not be attached to drop cords.

Drop cords may be extended from their outlets to another position by means of ceiling buttons.

Fixture Wiring.—Chain fixtures must be wired with flexible cord preferably single conductors so that each one may be laced through each link of the fixture chain. Chain fixtures are suitable for show windows.

One-eighth inch trade size sockets should be used so that loops may be screwed into the socket caps.

Chain fixtures that are attached to concealed knob and tube wiring or wooden moulding may be attached with fixture crow feet or tripods.

If the ceiling be of metal or plaster containing metal lath, a fibre or rubber canopy insulator must be used. Brackets or side wall fixtures must be wired with No. 18 fixture (solid) wire or larger. The ends of all pipes and bodies being reamed so that the burrs will not cut into the insulation. Pendants or fixtures that are constructed of tubing must be wired with solid fixture wire.

Combination fixtures that are attached to gas pipes must be equipped with insulating joints so that the fixture will be perfectly insulated and free from grounds, likewise must all fixtures that are attached to metal outlet boxes of B. X. and conduit wiring or knob and tube wiring where the fixture is to be secured to a gas pipe.

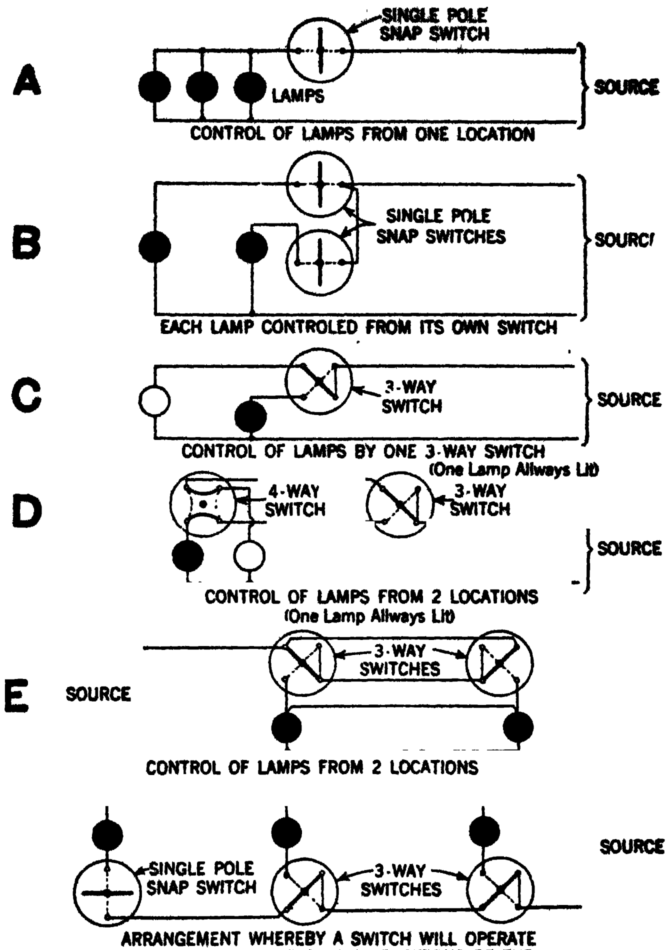


PLATE.—In the lamp control diagrams represented above, fig. A illustrates the connection when one single pole snap switch is used.

FIG. B shows how two lights (or two group of lights) can be controlled individually from a set of two single pole switches.

FIGS. C to F illustrate a series of special types of lamp control used in, for example, test circuits, or in any location where particular control schemes are desirable.

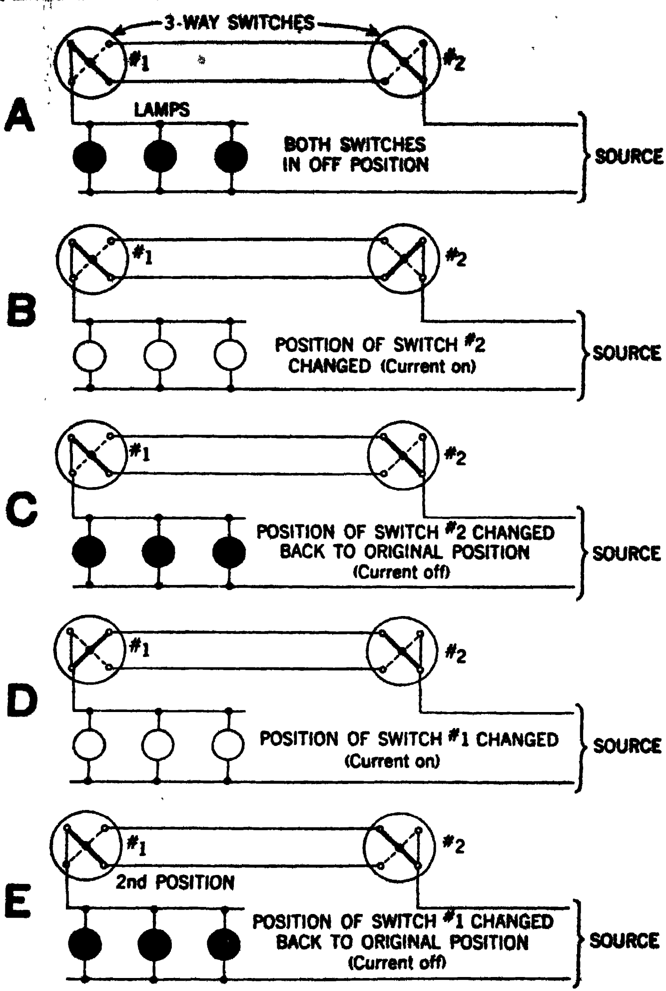


PLATE.—A convenient and often used method for control of a lamp or a group of lamps from two points by means of 3-way switches is shown in the diagrams. The lamps may be extinguished or lighted from either switch regardless of the position of the other. When both switches are in the positions shown in fig. A, the lamps are extinguished, and can be illuminated by the operation of switch No. 1 or 2. If as shown in diagram, No. 2 switch is operated the lamps will be illuminated, and can now be extinguished from either switch. A typical sequence of operation is shown diagramatically in figs. A to E.

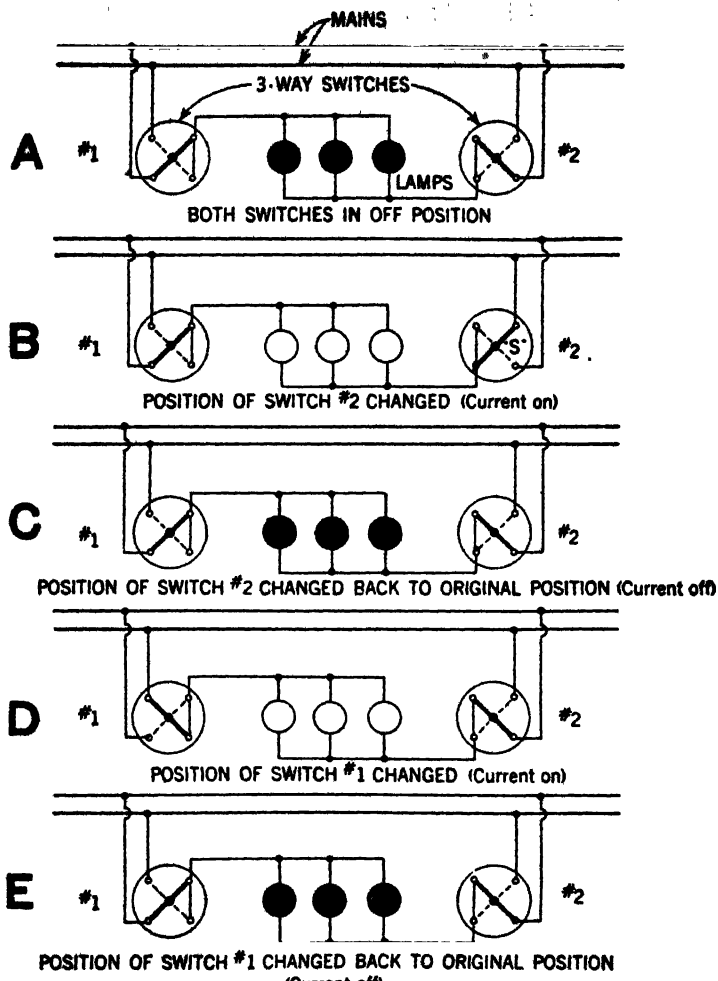


PLATE.—This connection provides an economical means of lamp control from two locations. Although not permissible under the National Electric Code it is shown only as an electrically possible circuit. As in the previous connections shown, both switches are in off position in fig. A, the lamps extinguished, and can be lit by operating either switch. If switch No. 2, fig. B, is operated to position "S" the lamps will be illuminated, and can be extinguished again from any one of the two switches. Figs. A to E inclusive shows the lamps lighted or extinguished, depending on position of switch No. 1, relative to the position of switch No. 2.

LAMP CONTROL FROM 2-CIRCUIT ELECTROLIER SWITCH

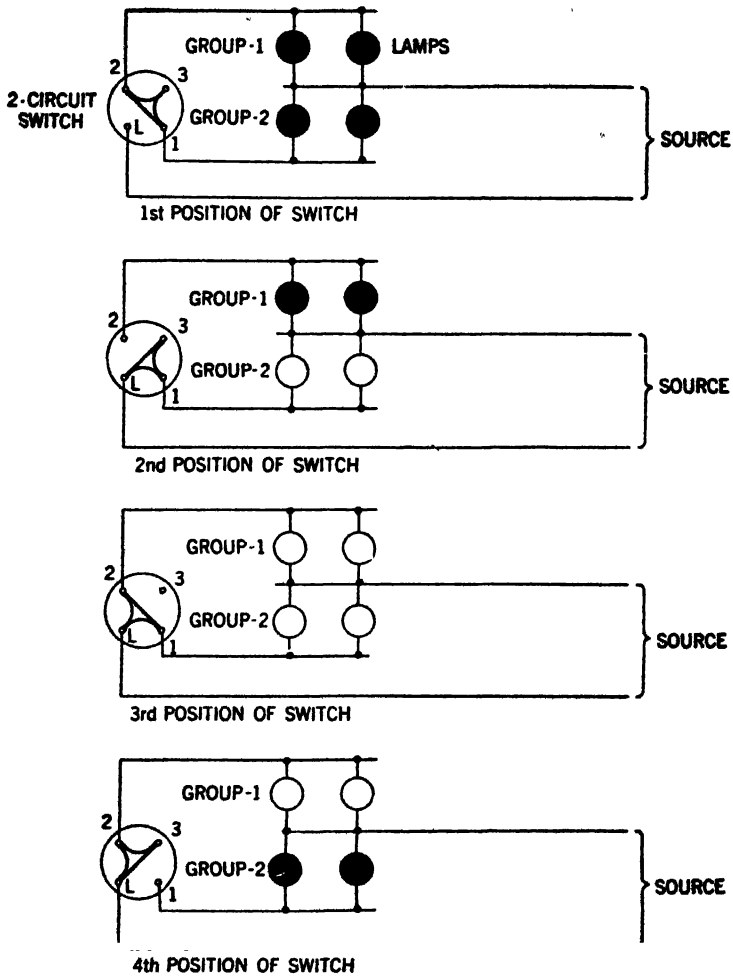


PLATE.—Large fixtures or electroliers are often wired so that lights can be controlled in two or more independent groups. As shown in the diagram the two groups of lamps are extinguished in the first position of the switch. When operating the switch to second position, group No. 2, will be illuminated. In the third position the maximum amount of brightness is obtained as both groups of lamps are illuminated, and finally in the fourth position, group No. 1 only is lit. This switch may not be considered as standard, it is only one of several arrangements.

LAMP CONTROL FROM 3-CIRCUIT ELECTROLIER SWITCH

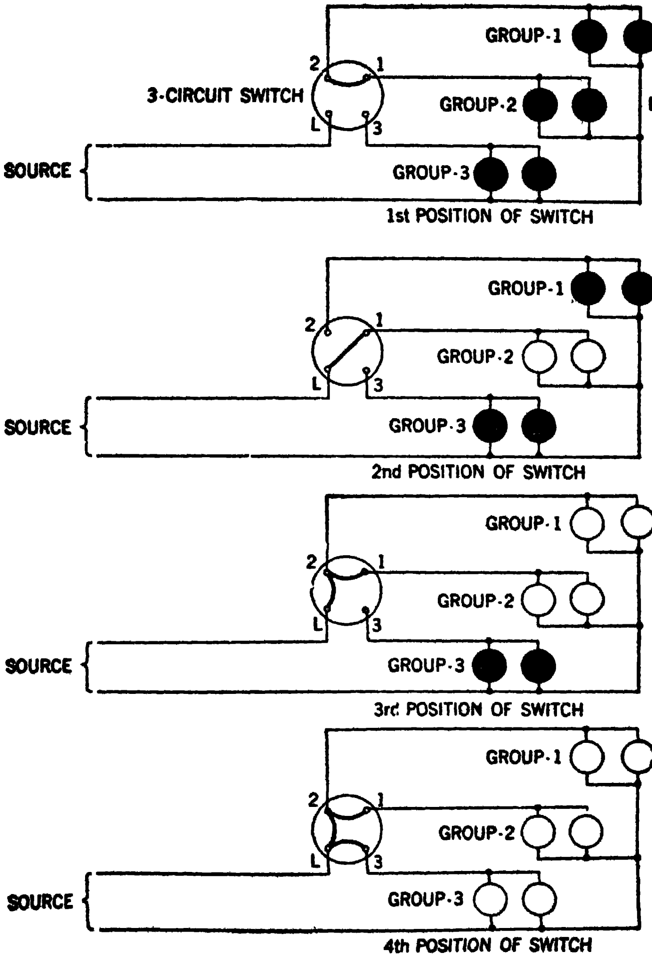
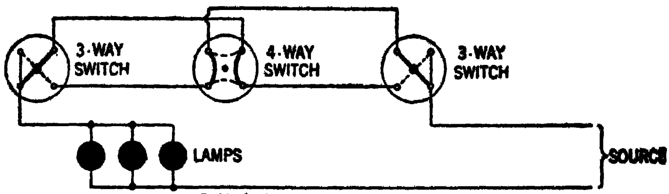


PLATE.—A 3-circuit electrolier switch from which three groups of lamps are controlled is shown above. The sequence of operation is depicted diagramatically and is principally the same as shown in the previous 2-circuit switch. In the 4th position maximum illumination is obtained, with all lamps lighted. The switch shown is typical only among a great variety of switches manufactured for electrolier or dome lamp control. The current carrying capacity of the switch as well as potential of the source to be connected should be considered for each individual application.

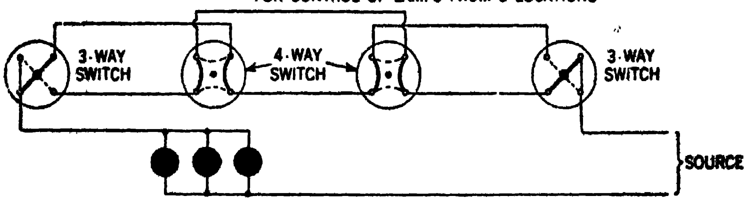
CONTROL OF LAMPS FROM MORE THAN ONE LOCATION BY MEANS OF 3 AND 4-WAY SWITCHES

A



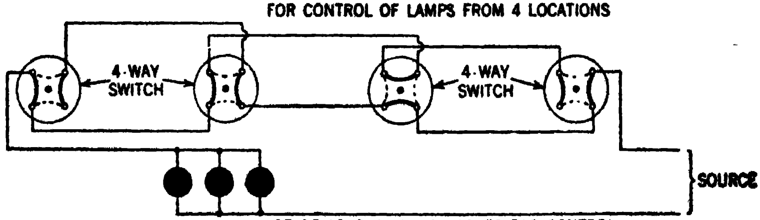
USE OF TWO 3-WAY AND ONE 4-WAY SWITCH
FOR CONTROL OF LAMPS FROM 3 LOCATIONS

B



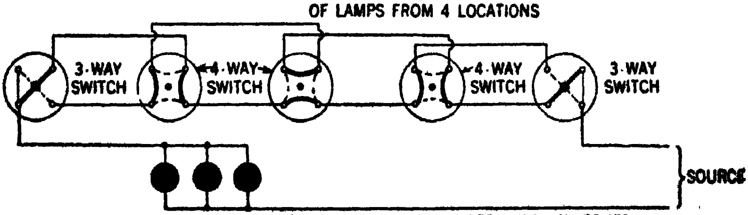
USE OF TWO 3 WAY AND TWO 4-WAY SWITCHES
FOR CONTROL OF LAMPS FROM 4 LOCATIONS

C



USE OF FOUR 4-WAY SWITCHES FOR CONTROL
OF LAMPS FROM 4 LOCATIONS

D



USE OF TWO 3-WAY AND THREE 4-WAY SWITCHES
FOR CONTROL OF LAMPS FROM 5 LOCATIONS

PLATE.—The series of connection diagrams shown in figs. A to D, illustrate the conventional methods of lamp control when using 3- and 4-way switches. With reference to fig. A, it is obvious that for any additional point of control desired a 4-way switch connected the same as the middle switch must be used. See figs. B to D.

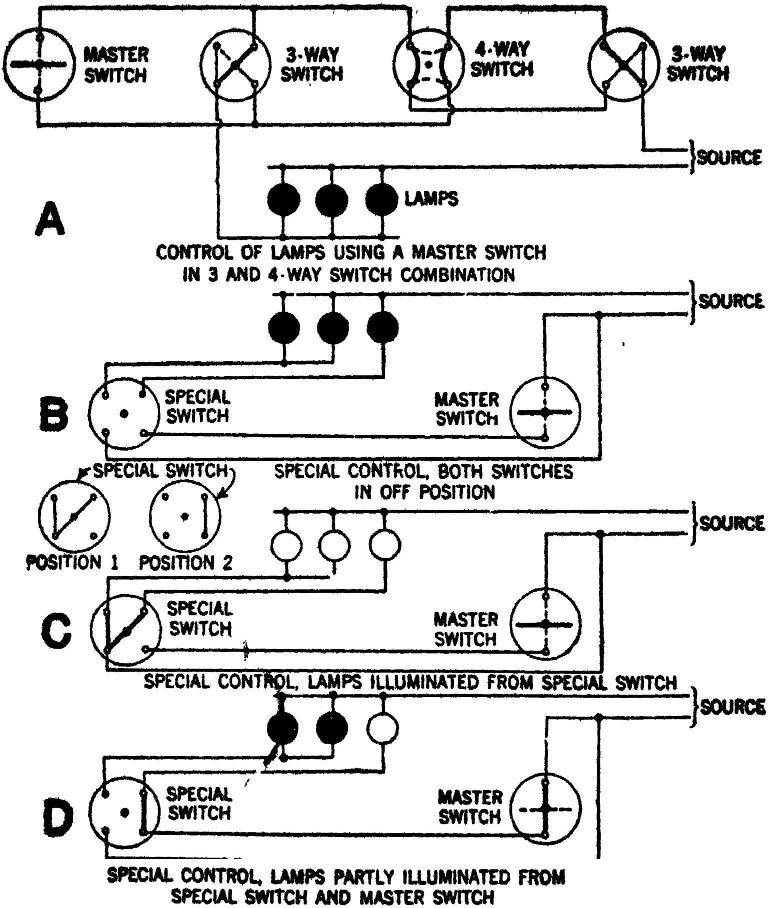


PLATE.—In residence lighting systems, it is often desirable to control all or part of the lamps from one central point (the owner's bedroom for example) irrespective of the position of the other switches used. This central point is as shown in the diagram provided with a master switch for complete control of the lamps. See fig. A. When control over a larger number of lamps is desired, it is necessary since the carrying capacity of the master switch is only about 15 amperes, to install a special form of switch, the connection of which is shown in figs. B to D. In this method the lamps are connected in two groups, the special switch is employed for the regular control of the lamps and each of these switches is connected to a common wire. By utilization of this form of control the lamps in each large fixture may conveniently be controlled from one point.

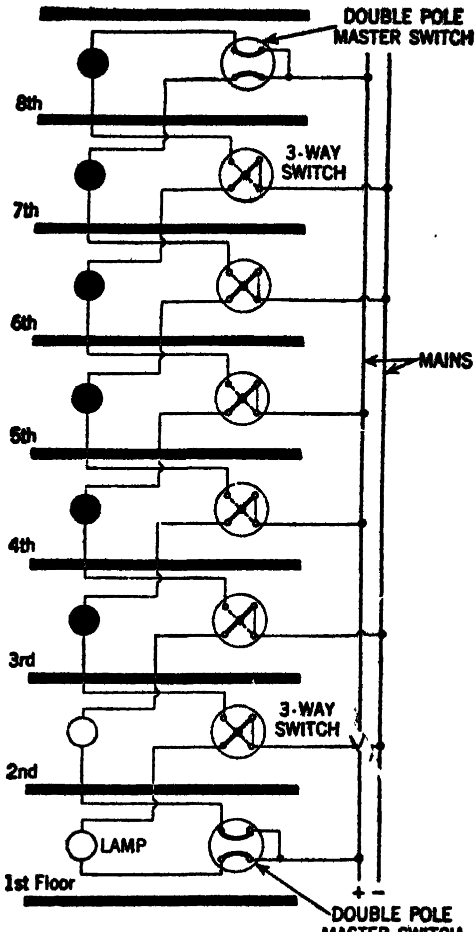


PLATE.—As shown in circuit diagram the switches used in this type of light control consist of two double pole switches, inter-connected on the first and last floor, and one 3-way switch for each floor. The sequence of operation is as follows: Closing switch on the first floor lights lamp on first and second floor. Turning the switch on the second floor extinguishes the light on the first floor and lights the lamp on the third floor, etc. This operation is continued until the top floor is reached, in other words the switch on each floor should be turned in passing. It can be readily seen that this light control arrangement lends itself to operation of lamps irrespective of number of floors encountered.

TEST QUESTIONS

1. *What is a service connection?*
2. *Name several methods of making service connections.*
3. *What is the requirements for installation of a distribution box?*
4. *What are the essential requirements of tube service?*
5. *What fittings are used on the service entrance?*
6. *Describe in detail the method of installing a conduit service.*
7. *How is the end of a conduit secured to the switch box?*
8. *Describe an underground service entrance.*
9. *How is a feeder layout for a large building made?*
10. *How many feeders should be provided in a large building?*
11. *What provision should be made for motors?*
12. *How should feeders be located?*
13. *Describe the method of cutting outlets.*
14. *How should a ceiling outlet be located?*
15. *Where should hole for wires be bored in joists?*
16. *Describe an outlet box.*
17. *What are knockouts in outlet boxes used for?*
18. *How are outlet boxes attached?*
19. *What is a fixture stud?*
20. *How should the wires be brought into an outlet box?*

21. *Give methods of installing outlet boxes in unfinished frame buildings.*

22. *Give method of cutting out switch box outlets.*

23. *Give method of passing by cross stud in partition when wires are run next to a door.*

24. *Give various methods of overcoming obstructions in partitions.*

25. *Describe the operation of dropping wires down outer walls.*

26. *What kind of obstructions are encountered along the outer walls?*

27. *Define the term "fishing".*

28. *Give method of fishing from outlet to outlet.*

29. *What is the function of a meter board?*

30. *Draw a wiring diagram showing how one or several lamps may be controlled from one location.*

31. *What method of wiring is used for control of two individual lights or a group of lights from two single pole switches.*

32. *What is the universal method used in the control of a light or group of lights from two locations?*

33. *Draw a wiring diagram showing how a lamp may be controlled from four locations with each control switch independent of the other three.*

CHAPTER 96

Wiring Requirements for the Home

Fundamental Wiring Requirements.—In the design of the electrical system, there are two basic factors to be taken into consideration. One factor is that of *safety*—compliance with the local governing rules and with the regulations of the *National Electrical Code*. The other factor is *function*—the designing of a system that will permit the occupants full and convenient use of the electrical equipment they now have and may procure in the future.

The *National Electrical Code* is prepared by the Electrical Committee of the National Fire Protection Association, which committee is representative of all the principal interests concerned with the safety of wiring. This Code is a standard adopted by the National Board of Fire Underwriters and has the approval of the American Standards Association. Together with local ordinances, frequently based upon the Code, and rules and regulations of local utility companies, the *National Electrical Code* provides a standard governing the installation, and to a certain extent, the use of electrical equipment.

From the *National Electrical Code*, under the heading of "Purpose and Scope" the following paragraph has been extracted:

The provisions of this Code constitute a minimum standard. Compliance therewith and proper maintenance will result in an installation reasonably free from hazard, but not necessarily efficient or convenient. This Code is to be regarded neither as a design specification nor an instruction manual for untrained persons. Good service and satisfactory results will often require larger sizes of wire, more branch circuits and better types of equipment than the minimum which is here specified."

From the foregoing extract of the Code, it is apparent that it does not necessarily follow that an electrical system meeting the requirements for safety also has the ability to serve effectively and efficiently. An effective and efficient electrical system depends upon:

1. Sufficient circuits of sufficiently large wire to carry the various loads without uneconomical voltage drop;
2. Sufficient outlets to allow for convenient use of electrical equipment;
3. Well placed "control centers" equipped with modern circuit protection;
4. High quality materials and workmanship.

When planning an electrical system there are certain fundamental and natural approaches to be followed. The size of the house, that is, its price class has a very definite influence on the extent of the electrical installation.

Planning of Equipment.—In estimating thc electrical requirements, it is necessary first to determine the equipment needed (lighting and appliances) both for present and future use. The ability of the owner to meet the initial cost and expense of operating the numerous labor saving devices is another factor to consider.

Appliances.—These are usually divided into two classes, namely:

1. Fixed appliances;
2. Portable appliances.

The number of labor saving appliances to be installed depends upon the size and type of house to be equipped.

Typical fixed appliances are such units as: Water heaters, washers, ironers, clothes dryers, ranges, refrigerators, dishwashers, garbage eliminators, etc.

If heating and air conditioning units be installed, provision must be made in the wiring plan for such units as: blowers, heating and cooling units, furnace motors, etc.

Typical portable appliances are: Electric clocks, coffee makers, curling irons, fans, hand irons, heating blankets, mixers, radio, roasters, sewing machines, shavers, sun lamps, toasters, vacuum cleaners, etc.

Lighting

There are three fundamental rules which must be followed at all times if the lighting of the home is to be truly good.

These rules apply whether the house is English, Colonial or Traditional. They also apply whether the equipment is built in or portable.

1. There must be sufficient light for all tasks to be performed in comfort without undue eye fatigue;
2. Light must be properly directed to avoid objectionable shadows and controlled to avoid harmful glare;
3. The equipment must be adopted for its purpose and appropriate in its surrounding.

Of these three fundamental rules the second is probably most generally disregarded, although it is extremely important, affecting as it does the eyes, nerves and general health.

Glare may be caused by a light source in the direct line of vision, by reflections from glossy paper or polished furniture tops, furniture glass tops, or by a decided contrast between the light source and its background.

All these conditions are frequently found in the home because of the low ceilings and the use of exposed lamps in wall brackets and ceiling fixtures, lamp shades which are too transparent and dark wall papers and draperies.

Light must in addition add charm, color and decorative beauty to a room. At the present cost of artificial illumination (cost per kilowatt hour) there is no excuse for following the old pattern of lighting based on habit, minimum cost and in the end result of poor and insufficient light.

Lighting Fixtures.—A good residence lighting fixture combines beauty with utility. Since there are many commercially available fixtures which provide this, there is ample room for individuality and personal expression.

In choosing a fixture it is essential to consider not only its own individual decorative value and its suitability to the room in which it is to be used, but also the illumination it provides, its freedom from glare and the ease with which it can be maintained and cleaned.

The maintenance factor plays a rather important role, particularly where fluorescent fixtures are employed, because here there are three components involved, namely: *The ballast, starter* (glow switch) and *lamp.*

Lighting in the home should conform to the principles of good illumination because one is associated with it so intimately, but the style should be chosen to suit the owner's tastes and architecture of the home.

Therefore, in planning home lighting, provide outlets for ceiling fixtures, wall brackets, portable lamps and lighting from coves, valances, bookcases, etc., for only by a combination of two or more of these types of lighting can there be sufficient flexibility to meet varying eye tasks and schemes of decoration in the home.

Lighting of the Entrance.—The lighted entrance not only should make the path, steps, house number and bell clearly visible, but also should create a hospitable atmosphere, and give a distinguished air to the home. The architecture of the entrance door determines whether weatherproof lanterns, singly or in pairs, or built-in lighting can be used. As a factor of safety, light on the steps is most important.

Poorly chosen entrance lights that are glaring sometimes make reading the house number impossible, and very often house numbers are thoughtlessly placed many feet from the entrance lights. Most easily seen are the illuminated house numbers.

When the house is located at more than average distance from the sidewalk, the illuminated house number may be placed at the driveway entrance. Another method of lighting the front of the house is by means of small floodlights concealed in the shrubbery.

The entrance fixtures should be controlled from just inside the hall door, the switches being placed on the lock side of the door, not the hinge side. Weather-proof convenience outlets should be placed outside the house for use of decorative seasonal lighting and electrical garden equipment.

Vestibule between the hall and entrance are usually small and can be lighted by a ceiling fixture controlled by a switch located adjacent to the entrance switch.

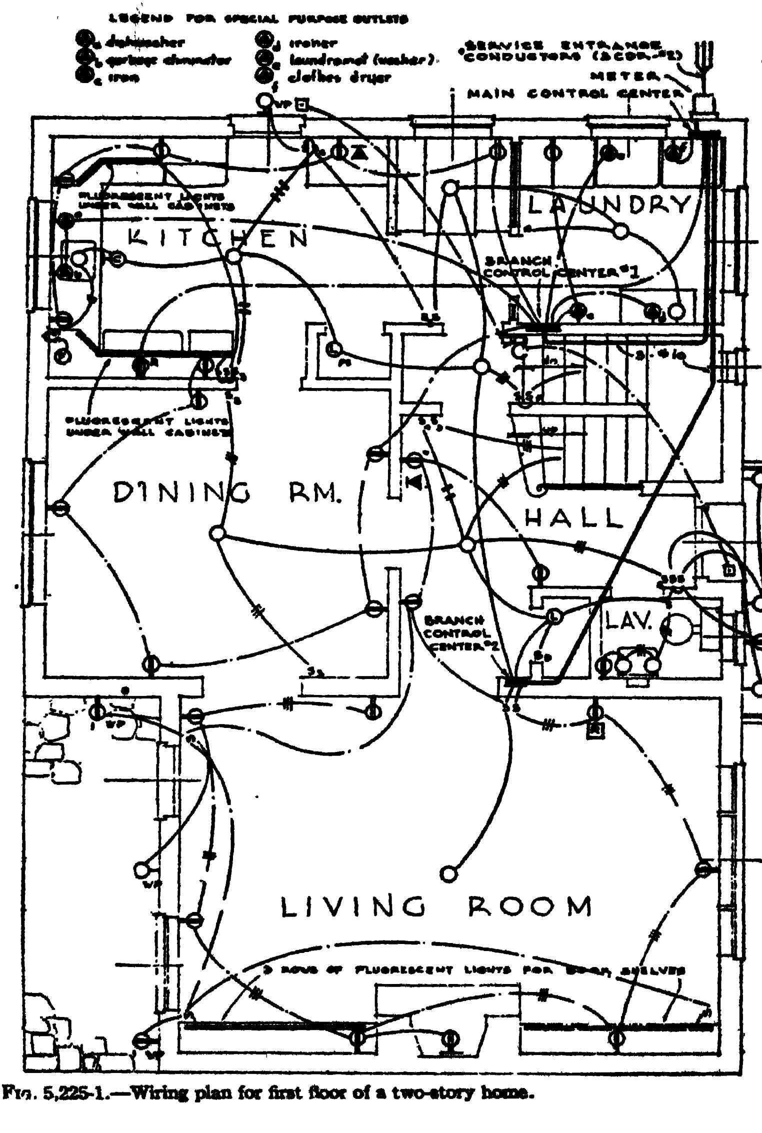


FIG. 5,225-1.—Wiring plan for first floor of a two-story home.

Lighting the Halls.—The hall is no longer a passageway from door to living room, but another room. In this room guests obtain the first glimpse of the home. Whether they are greeted by gloom or cheer depends on the lighting. In the average hall a suspended lantern, close fitting fixture, or shaded candle type fixture is appropriate. A lamp on a console table, torchieres, or luminous panels around a mirror may be effectively used.

Light from the hall fixture downstairs should be supplemented by light from an upstairs fixture. This combination supplies light for safety on the stairs. Both hall fixtures should be controlled by separate switches upstairs and down, so that they may be turned on or off from either floor. It is important that convenient outlets be installed in the halls to permit the use of lamps and electrical appliances.

Lighting the Living Room.—From the standpoint of lighting, the living room is the most important room in a home. Because of the wide range of living requirements in this room the lighting must be adequate for severe seeing tasks, such as reading or sewing. All lamp bulbs should be shaded to avoid glare and there should be light in enough places to avoid deep contrast. Generally, there are three types of lighting units used in the living room—ceiling fixtures, wall brackets, and floor and table lamps. All three of these types can be pleasingly employed in a single room.

The ceiling fixture is not a thing of the past. Fixtures, to-day are not only decorative in themselves, but produce soft, general illumination. The choice between a pendant or close-fitting ceiling fixture depends upon the ceiling height. For the modern room of low ceiling, the fixture may be built-in or mounted close to the ceiling. The duty of a ceiling fixture, regardless of style or type, is essentially to provide general illumination may be supplied by indirect or semi-indirect portable lamps.

Wall brackets should be considered for their decorative value only and not as a source of lighting when reading, sewing, or writing. Although the newer totally-indirect wall urns add greatly to the general lighting in a room, they should be supplemented by other light for reading. The most important thing to remember about these lighting fixtures is that the lamp bulbs must be shaded. It is always wise to plan the location of wall brackets in order that they will not interfere with the hanging of pictures or tapestries.

No living room ceiling fixture or wall bracket is designed to provide adequate local light for reading or other visual work at the various chairs or the davenport. At all points where severe visual work must be done, floor and table lamps or other lamps which have been carefully designed to provide comfortable seeing conditions in the home should be used. In this way enough general lighting is provided to eliminate excessive contrast between the area near the lamp and the rest of the room. Greater flexibility

may be obtained by using the three-lite lamp inside the translucent bowl. These lamps contain two filaments which may be operated together or separately. Illumination ranging from low, pleasant light for conversation to light adequate for sewing or reading is thus made available in a single unit by a simple turn of the switch.

Built-in lighting has only been mentioned, for the subject is too large to be treated in detail. This type of lighting must be carefully planned during the blueprint stage as it usually takes the form of recessed fixtures in the ceiling, coves around or in certain portions of the room; glass panels or grilles in walls, archways, beams or columns. Lighting built into the architectural features of a room adds grace and distinction to the decorative theme as well as to the lighting. Troughs of light may be installed to form a window ledge, or they may be placed behind large mirrors, window valances and in bookcases.

For the effective use of lamps as well as electrical appliances, there must be a sufficient number of convenience outlets. Every wall space large enough for a piece of furniture should contain a *duplex convenience outlet. Minimum requirements demand that a duplex outlet be placed every twelve feet on long wall spaces.* At least one outlet flush in the top of the mantel should be provided for an electric clock or decorative lighting urn. Ceiling fixtures and wall brackets should be controlled by a switch at the main entrance of the living room. If there is another entrance or exit, an additional switch should also control the ceiling light at this other doorway. In this way the lights may be turned on or off at either doorway. If a ceiling fixture is omitted, the wall brackets or convenience outlets should be similarly controlled from wall switches.

Lighting the Dining Room.—Pleasing lighting will add not only to the decoration of the dining room, but also to the enjoyment of the meal. Regardless of the diversity of activities in this room, it is essential that the room be bright, cheery, and free from glaring, exposed lamp bulbs.

There are several methods of lighting the dining room correctly. The most popular is the pendant fixture suspended over the table. If this is used, all lamp bulbs should be shaded to direct the light downward and to avoid harsh light striking the faces of those seated at the table. Wall brackets too are a pleasant background and are desirable if properly shaded.

There is a trend toward lower ceiling heights, and the combining of living room and dining areas necessitates close fitting ceiling fixtures for better proportion and balance. If the dining room table is also used as a study or work table, it is essential that an ample quantity of glareless light be provided. Ceiling fixtures or wall brackets should be controlled by switches at the main entrance of the dining room, and also at the kitchen

door. The dining room is also adaptable to colored lighting. Amber, moonlight, or other desired color effects may be obtained by especially designed fixtures or built-in fixtures.

White or colored lumiline, tubular or florescent lamps, installed in plaster, metal or glass coves around the room or at opposite ends of the room, make possible many interesting effects.

Convenience outlets are necessary for the use of electrical appliances on the table or at the buffet. The best location depends on the placement of the table.

Lighting the Kitchen.—The kitchen is the workshop of the home, so it is vitally important that this room be made as cheery and comfortable as possible. There are two requisites for a well-lighted kitchen. The first is a central ceiling fixture—usually a single diffusing enclosed unit. Some modern kitchens have totally indirect fixtures. Light colored walls and ceilings assist in directing much of the light downward and minimizing shadows.

The kitchen should have plenty of light everywhere. It should be so arranged that a worker, regardless of whether work is being done at the sink, range or work-table, is never working in his or her own shadow. This is unavoidable when a single ceiling fixture is used, since the location of the various work-centers in the kitchen frequently makes it necessary to stand with one's back to the light source.

Therefore, the second requisite for a well lighted kitchen is local lighting over the range, sink, and other work centers. The simplest remedy is a pendant fixture or bracket over the sink and the range. A glass shade must be used to protect the eyes from glare and to direct the light downward. In the more modern kitchens, Mazda lamp bulbs are recessed over the sink and covered by diffusing panels of glass. Lumiline or flourescent lamps are ideally suited for installing over the range, sink or under the kitchen cabinets to illuminate the work table.

In the pantry or butler's pantry a small, close-fitting ceiling fixture will amply light the shelves and cupboards, while for the breakfast alcove, a pendant-shaded fixture or an indirect unit is very satisfactory.

It is important to have plenty of convenient outlets in the kitchen. Certain appliances such as the toaster, percolator, mixer and roaster are used at table height and outlets should be 42 inches above the floor. Clocks and ventilating fans are usually mounted high, so that these outlets may be six to eight feet from the floor. Larger appliances such as the dishwasher and refrigerator usually are best served from special locations. The range, of course, needs not only a special location but also special wiring.

Lighting the Bedroom.—The bedroom in many homes is used as a study and reading room or a room in which to sew, in addition to a place in which to sleep. It is unfortunate that ceiling fixtures are being omitted in so many bedrooms, because they provide a high level of illumination not usually provided by boudoir lamps. A ceiling fixture or wall brackets should be controlled from a wall switch just inside the bedroom door. All too often, furniture arrangements are limited if the bedroom is lighted only by wall brackets and, therefore, a ceiling fixture for general illumination is more desirable. A semi-indirect or totally indirect fixture is recommended because it produces very pleasant, soft illumination. If a candle type fixture is used all lamp bulbs must be shaded.

There are three places in the bedroom where local or special lighting is needed—the vanity dresser, the bed, and the boudoir chair or chaise longue. Boudoir lamps on the vanity should be tall with light colored shades to permit adequate light on both sides of the face. For reading in bed a lamp on the wall, table or floor can be used; but it must cast a wide circle of light over the book or magazine with no glaring light striking the eyes.

Most bed lamps are hopelessly inadequate as they are only bits of decoration and usually glaring. A lamp with a white diffusing bowl under the shade gives the most comfortable light. A floor lamp providing a wide spread of glareless diffused downward light alongside the boudoir chair or chaise longue provides adequate, soft light for mending, knitting or reading, while a small lamp placed under the bed in the baseboard will flood the floor with light, making it easy to move about without disturbing other occupants of the room. Convenient outlets for these lamps should be provided in each wall.

Every closet over two feet in depth should be lighted. Usually this light is installed inside on the wall or in the ceiling just above the door so that light is thrown back on the clothes and shelves. The wattage of the lamp depends upon the size of the closet, but these lamps are used for such a short period of time that the current is negligible, even with high wattage lamps.

Lighting the Bathroom.—The mirror in the bathroom is the most important one in the house. Gone is the old idea that a single lighting fixture is sufficient. The best illumination is supplied by two brackets about five feet, six inches from the floor. Two units help to erase shadows and give the same amount of light on both sides of the face. All bulbs should be shaded with diffusing glass. The ideal lighting of bathroom mirrors is accomplished by framing the mirror on top and two sides with built-in panels, and lighting from lamps concealed behind the frosted glass.

Unless the bathroom is exceedingly small (less than 60 square feet) it should have a ceiling fixture. Usually an enclosing globe controlled from a wall switch just inside the door will be satisfactory. If a central lighting unit has been omitted, the mirror light should be similarly switched. Oftentimes the shower or tub needs its own light. These lights are usually mounted flush with the ceiling and are waterproof units. An added light of great convenience is a night light installed in the baseboard. A convenient outlet placed at the right of the mirror is necessary for an electric razor, curling iron, or sun lamp.

Lighting the Attic.—The attic space needs a ceiling light. This might be an RLM standard dome reflector controlled from a switch at the foot of the stairs, and also at the head of the attic stairs. At least one convenience outlet should be provided.

Lighting the Basement.—The basement, like the attic, is often neglected. The basement might be divided into stairway, laundry, workshop, furnace room and recreation room. Each room needs its own planned lighting.

Lighting the Stairway.—More accidents occur on dark basement stairs than on any other place in the home. A glareless light, usually at the foot of the stairs, and controlled by three-way switches from the head of the stairs and from the basement should be installed. A pilot light in the switch at the head of the stairs may be used to show when this light is left burning.

Lighting the Laundry.—The laundry room needs one or more ceiling lights, depending on the size of the laundry. White diffusing globe luminaries, or silvered bowl lamps are usually satisfactory. In addition to the ceiling units, local light is imperative in the laundry at the wash tubs, ironing boards or ironer. Convenient outlets should be provided for the use of electrical washers and ironers.

Lighting the Workshop.—The work-bench should be properly illuminated with enough light well placed to avoid shadows. RLM reflectors or Glassteel diffusers installed over the work bench direct light downward for close mechanical work. A duplex outlet is needed for the use of electrical tools.

Lighting the Furnace Room.—RLM reflectors mounted at the ceiling should be installed at the furnace and coal bins. These units concentrate the light downward and supply good light for easy adjusting of heat controls and reading meters.

Lighting the Recreation Room.—Many home owners to-day are devoting a portion of the basement to a recreation room. In most cases

low ceiling heights necessitate close fitting or recessed lights. In addition to general illumination from fixtures, portable lamps provide seeing light for reading or card playing. Very often a small bar is installed, having special more decorative lighting. Sufficient convenience outlets for lamps, radio, electric trains, and other toys, as well as appliances should be provided.

Lighting the Garage.—Light is absolutely necessary at the rear door and garage, both from a convenient and safety standpoint. The rear door light can be a simple bracket or porch ceiling light. The exterior garage light may be a RLM dome reflector or a more decorative waterproof lantern. It should be controlled by a switch inside the entrance of the garage, and by another switch inside the most convenient door to the house.

The interior of the garage can be efficiently and satisfactorily lighted by RLM dome reflectors. One should be mounted over the engine hood of the car and the other over the work bench. Convenient outlets should be provided in the garage for use of lamps on extension cords and electrical tools.

Circuits and Control Methods

Master Switch Control.—In determining the number of outlets required in each room a feature worthy of consideration is to have a master switch to control certain outlets from the owner's bedroom. This master switch makes it possible to turn on lights located at various points inside or outside the house, independently of local switch controls. That is, when the master switch is in the *off* position, the circuits under its control may be controlled by the local switches.

On the other hand, when the master switch is in the *on* position, the outlets under its control will all be *on* regardless of whether the local switches be *on* or *off*. Figs. 5,225-2 and 5,225-3 shows wiring connections for one and two branch circuits, respectively. Where more than two branch circuits are to be controlled, single-pole magnetic switches are recommended in each circuit, actuated by a single-pole master switch. Other wiring schemes are shown following page 3,318.

Electrical Circuits Required.—After the number and type of outlets have been determined and fixed on the plan, it remains to arrive at the number and type of branch circuits required to

serve these outlets. There are several types of circuits required in the distribution of electrical energy throughout the home. They may be divided into three groups, as follows:

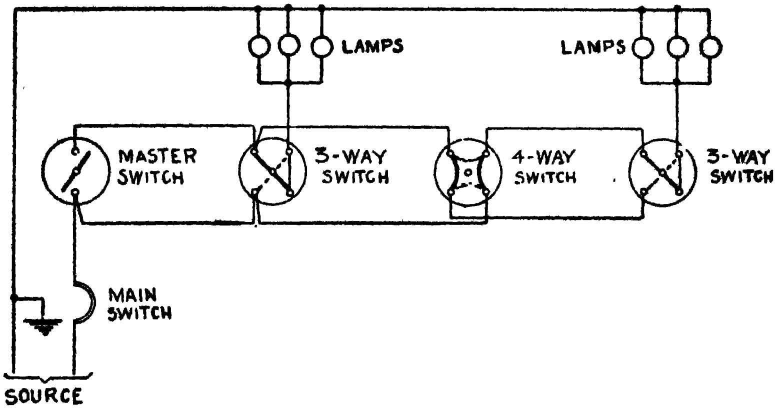


FIG. 5,225-2.—Typical wiring diagram showing master control for one circuit.

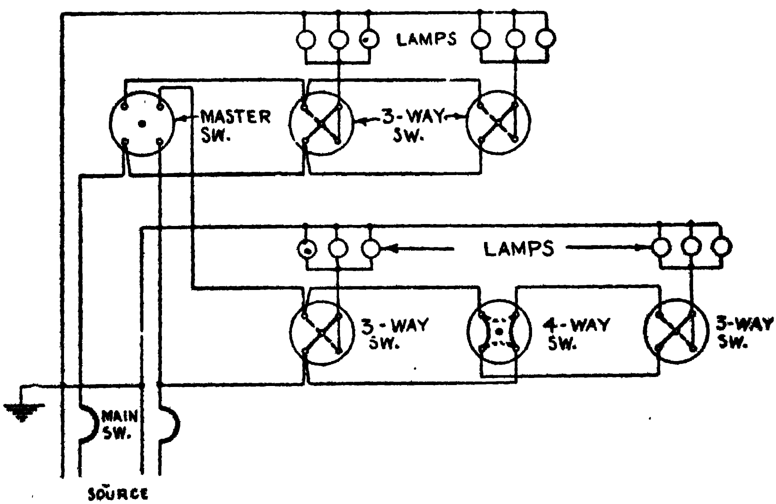


FIG. 5,225-3.—Typical wiring diagr showing ntrol for two circuits.

1. General purpose (15 amp.) circuits;
2. Appliance (20 amp.) circuits;
3. Individual equipment circuits.

General Purpose (15 Amp.) Circuits.—These are used to serve fixed lighting outlets and convenient outlets in areas other than those served by the "Appliance Circuits" described in the following paragraph.

No fixed appliances with a total rating of more than six amperes (690 watts, 115 volts), nor single portable appliance with an individual rating of more than 10 amperes (1,150 watts, 115 volts) *should be planned* for use on this type of circuit, because other loads may be connected to the circuit at the same time. This type of circuit operates on 115 volts, having a circuit conductor of No. 14 minimum (for runs not exceeding 30 feet) protected by a 15 ampere circuit breaker, No. 12 wire is recommended as minimum.

Appliance (20 Amp.) Circuits.—These serve all receptacle outlets (other than outlets for clocks and outlets served by individual equipment circuits) in kitchen, laundry, pantry, dining room, breakfast room, utility room and garage. Appliances only (no lighting) are to be connected to this type circuit.

No single appliance with a rating of more than 15 amperes (1,725 watts, 115 volts) *should be planned* for use on this type of circuit, because other loads may be connected to the circuit at the same time. This type of circuit operates on 115 volts, having circuit conductors of No. 12 minimum (for runs not exceeding 45 feet) protected by a 20-ampere circuit breaker.

Individual Equipment Circuits.—These are for use in serving single appliances or single equipment units. These circuits are two or three wire, and operate on nominal 115/230 or nominal 120/208 volts.

Single Branch Circuit Conductors.—Although No. 14 conductors may be used for 15 ampere circuits, No. 12 is recommended as the smallest size conductor to use in wiring the home. This will permit additional use of electrical equipment through better lighting and more appliances.

Circuits supplying individual pieces of equipment should have a carrying capacity sufficient for the load which they supply. The maximum demand for determining size of circuits for cooking ranges may be calculated at 7,000 watts, for ranges rated up to 12,000 watts.

The *National Electrical Code* classifies circuits as 15, 20, 25, 35 and 50 ampere branch circuits and individual branch circuits. The minimum size of conductors that can be used for any circuit is the size having a carrying capacity equal to the rating or setting of the over-current device protecting the circuit.

If conductors of a larger size are used in order to reduce voltage drop, the change in size of the conductor does not change the classification of the circuit. For example, if the rating of the over-current device is 20 amperes, the circuit is a 20-ampere circuit, regardless of whether the conductors are Nos. 12, 10, or larger.

Location of Control Centers.—In the past it has been the custom to locate all circuit protective disconnects in one location. This location all too frequently was in the basement or other equally inconvenient space. It is becoming more and more the custom to place these control centers near the load centers. The kitchen, laundry and utility rooms have the greatest portion of the electrical load. For this reason, it is desirable to locate at least one of the control centers in such area.

This will result in the branch circuits being short in length, because of their proximity to the various lighting and appliance outlets. In addition to greater convenience to the occupants, this method of location of control centers means less voltage drop and gives more efficient operation of the electrical equipment, at a lower operating expense, and frequently at a lower initial cost. Figs. 5,225-4 and 5,225-5 shows schematically interior electrical systems.

In laying out an installation, therefore, every reasonable effort should be made to place control centers in readily accessible locations, at which points the protective disconnects controlling the several branch circuits can be grouped for convenience and safety of operation. The control centers, available in the postwar market, have been reduced in size and improved in appearance. The assembly is very compact and is designed for flush mounting when desired.

Determining Number and Size of Control Centers.—The *main control center* (service equipment) should be restricted to

six protective subdivisions. There may be six breakers, either single or double pole. By keeping the subdivisions within six, the main disconnect may be omitted, according to the *National Electrical Code.* (Some local regulations may demand a main

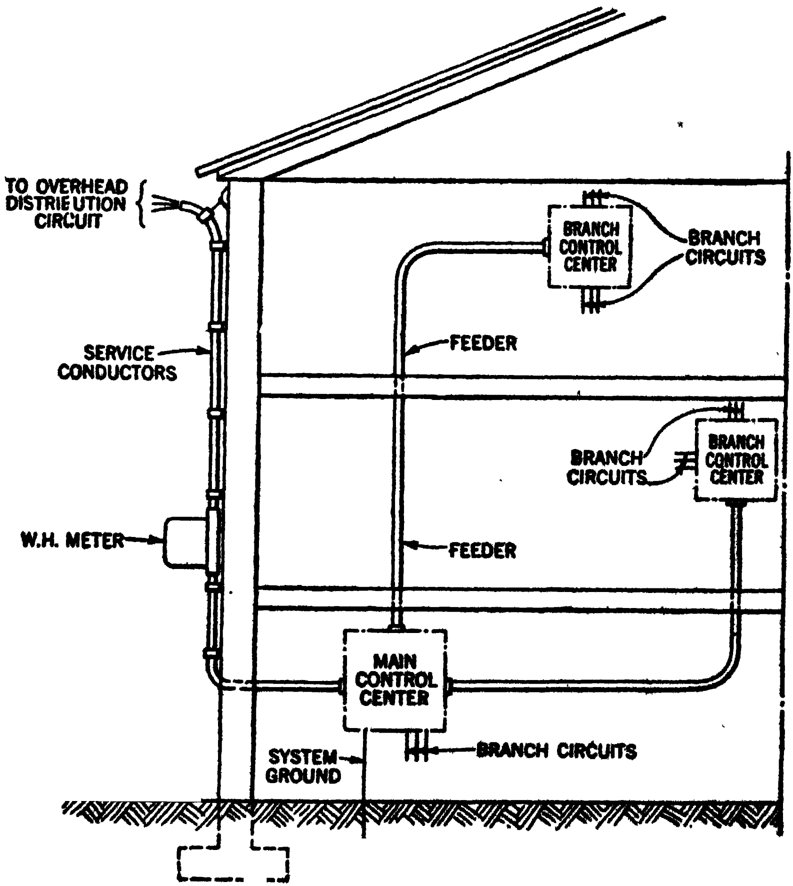


Fig. 5,225-4.—Schematic arrangement of typical distribution system for a

disconnect, even though the subdivisions are six or less. Therefore, this question should be checked with the local authorities having jurisdiction.)

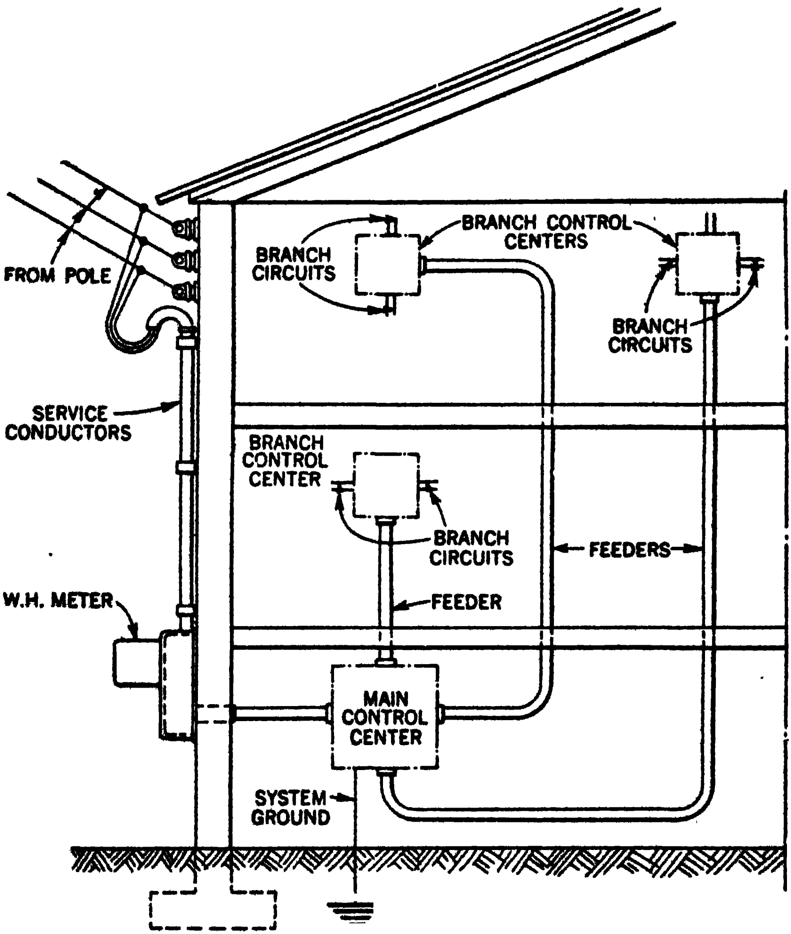


FIG. 5.225-5.—Schematic arrangement of typical distribution system for a large home.

The *branch control centers* should be restricted to eight poles; that is, eight single poles or four double poles, or four single poles and two double poles. Generally, where more protective disconnects are required, additional control centers should be installed.

Sizing Feeders and Service Entrance Conductors.—There are two steps in the process of determining the maximum load that feeders and entrance conductors will be required to carry. First, a reasonable estimate must be made of the probable connected load and second, a reasonable value of the demand factor must be assumed.

In very small electrical installations it is practical to assume that the entire connected load may be in operation at one time. This means the maximum demand will be 100% of the total connected load, giving a demand factor of 100%. As the size of the electrical installation increases, it is reasonable to assume that there will be some diversification of the load.

In the computations given later in this chapter, a demand factor has been applied where four or more fixed appliances (served by individual equipment circuits) in addition to a cooking range, are provided. The exact value of the demand factor *should be checked with the local authorities* responsible for the governing regulations.

In planning the backbone of the electrical system, that is, the service, feeders and control centers, the future demands that may be placed upon the system should be carefully considered. Conductors and control centers larger than actually required to serve the initial installation can be provided at a relatively small additional expense if done at the time of construction.

The feeders and entrance conductors must, of course, carry the load to which they may be subjected and with a minimum voltage drop. It is reasonable to assume that there will be some diversification; that is, that the entire connected load will not be in use at any one time.

It is recommended that no feeder be of a smaller size than No. 12—20-ampere circuit breaker rating.

Service Entrance.—Every installation must include wires to bring current into the building, with proper means for disconnecting the service, for over-current protection, for grounding, etc. All these needed accessories are known as the "Service Entrance."

The Service Entrance consists of five parts:

1. Service drop (supply line);
2. Service entrance conductors;
3. Meter;
4. Disconnecting means and overcurrent protection;
5. Ground.

In general, the point of attachment of a service drop to a building should be not less than 10 feet above ground. Furthermore, the minimum clearance for service drop conductors should be 10 feet above sidewalks and 18 feet above driveways, alleys and public roads. Underground service is very often desirable, principally from the standpoint of appearance. *Consult with the local utility company* early in the development stage as to type of service available, the point of contact at the building and the question of overhead versus underground service connection.

Sequence.—A commonly accepted sequence arrangement is shown in fig. 5,225-6. The arrangement is permitted by the *National Electrical Code* where the supply system is *a.c.* and the voltage between conductors does not exceed 300.

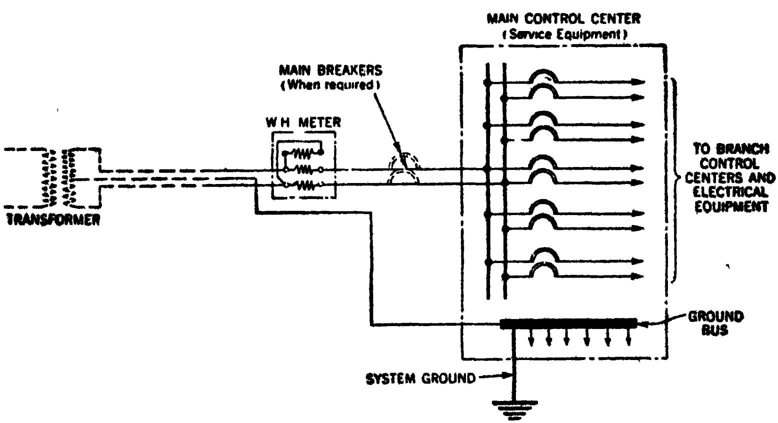


FIG. 5,225-6.—Showing common sequence of service ar ent.

The meter is mounted on the outside of the building. The service equipment (main control center) is located inside the building at a readily accessible point nearest the point of entrance of the service conductors. As previously stated, the number of circuit breakers that may be used as service equipment is up to and including six. The subdivisions may be two-or three-wire.

Feeder Calculations

There are three principal methods used in calculating illumination requirements. They are:

1. Watts per square foot*;
2. Lumen method;
3. Point by point.

Although all three methods are used, the simplest way to arrive at the required wattage in such simple structures as homes, is by the use of the *watt per square foot method*.

In calculating the load on the basis of watts per square foot, the floor area shall be computed from the outside dimensions of the building, apartment or area involved, and the number of floors, not including open porches, garages, in connection with dwelling occupancies, nor unfinished spaces in basements or attics.

The procedure in computing feeder sizes for home requirements may best be shown by the following examples:

Example.—It is required that a single family dwelling be wired in accordance with the *National Electrical Code*. The dwelling has a floor area of 800 square feet, exclusive of unoccupied cellar, unfinished attic and open porches. With reference to fig. 5,225-7 showing the control center and feeder layout, what service capacity and feeder sizes are required when the load is assumed as two watts per square foot.

*NOTE.—According to the *National Electrical Code* apartments, single and multi-family dwellings should have a minimum illumination of two watts per square foot. It is also recommended that in occupancies for dwelling purposes, in addition to any branch circuit supplying appliances a 15 ampere branch circuit be installed for each 500 square feet of floor area.

Solution.—The service capacity and feeder sizes may be obtained as follows:

Service Capacity

General Lighting 800 sq. ft. × 2 watts	= 1,600 watts		
Small Appliances	= 1,000		
	2,600		
	First 2,500	at 100% = 2,500 watts	
	100	at 30% = 30	
Range—7,000 watts		Demand = 7,000	
Water Heater	2,000 watts		
Heating Unit	700		
Washer	350		3,050
			12,580 watts

Assuming 3-wire, 115/230-volt service:—12,580 ÷ 230 = 54.7 amperes.
No. 4 Conductor required (70-amp., 2-pole breaker).

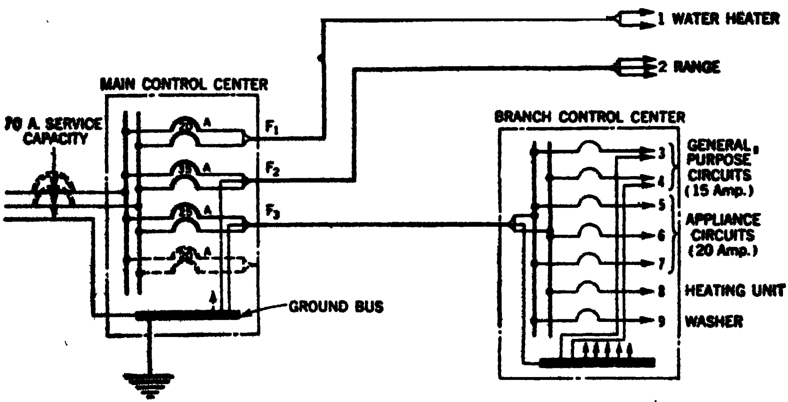


Fig. 5,225-7.—Schematic wiring diagram showing feeder layout for one branch control center.

Feeder No. F1

Circuit 1:—Water Heater .... 2,000 watts
At 2-wire, 230 volts:—2,000 ÷ 230 = 8.7 amperes.
No. 12 Conductor recommended (20-amp., 2-pole breaker).

Feeder No. F2

Circuit 2:—Range .... 7,000 watts
At 3-wire, 115/230 volts:—7,000 ÷ 230 = 30.4 amperes.
No. 8 Conductor required—Neutral No. 10 (35-amp., 2-pole breaker).

Feeder No. F3

Circuits 3-4:—Lighting 800×2 watts = 1,600 watts
Circuits 5-6-7:—Small Appliances . . . = 1,000

	2,600		
First	2,500	at 100% =	2,500 watts
	100	at 30% =	30
Circuit 8:—Heating Unit		=	700
Circuit 9:—Washer		=	350
			3,580 watts

At 3-wire, 115/230 volts:—3,580÷230 = 15.6 amperes.
No. 10 Conductor recommended (25-amp., 2-pole breaker).*

Feeder No. F4

This is a spare feeder circuit for future use (20-amp., 2-pole breaker).

Example.—It is required to compute the feeder sizes required for a single family dwelling having one main and two branch control centers as shown in fig. 5,225-8. What will be the minimum size feeders (or service conductors) required for this layout when the computed floor area is 1,200 square feet, assuming two watts per square foot?

Solution.—The service capacity and feeder sizes will be obtained as follows:

Service Capacity

General Lighting. 1,200 sq. ft. × 2 watts = 2,400 watts
Small Appliances . . . . = 1,500

	3,900		
First	2,500	at 100% =	2,500 watts
	1,400	at 30% =	420
Range—9,000 watts		Demand =	7,000
Water Heater	3,000 watts		
Heating-Air Cleaning Unit	800		
Washer	350		
Bathroom Heater	1,000		
	5,150	at 80% =	4,120
			14,040 watts

Assuming 3-wire, 115/230-volt service:—14,040÷230 = 61.0 amperes.
No. 4 Conductor required (70-amp., 2-pole breaker).

*NOTE.—It is important that proper voltage and regulation be maintained for satisfactory operation of the washer. Therefore, if voltage impressed at point of service entrance is low, or irregular, it is recommended that the feeder and its protective device be *increased one size.* Consult local utility company.

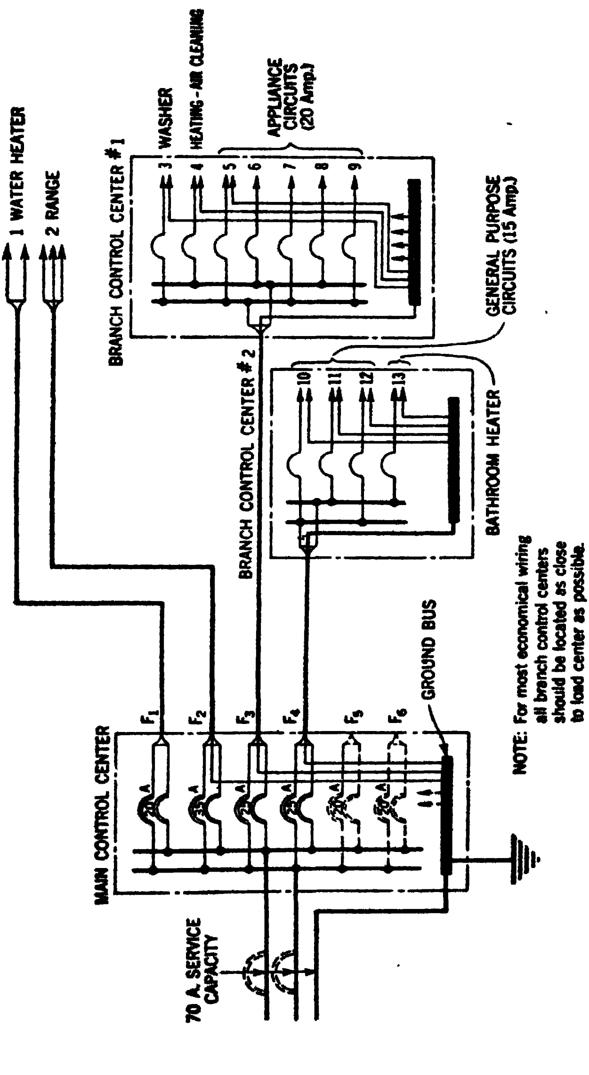


FIG. 5,225-8.—Schematic wiring diagram showing feeder layout for two branch control centers.

Feeder No. F1

Circuit 1:—Water Heater............................3,000 watts
At 2-wire, 230 volts:—3,000÷230 = 13.0 amperes.
No. 12 Conductor recommended (20-amp., 2-pole breaker).

Feeder No. F2

Circuit 2:—Range....................................7,000 watts
At 3-wire, 115/230 volts:—7,000÷230 = 30.4 amperes.
No. 8 Conductor required—Neutral No. 10 (35-amp., 2-pole breaker).

Feeder No. F3

Circuit 3:—Washer....................................	350 watts
Circuit 4:—Heating-Air Cleaning Unit.................	800
Circuits 5-9:—Small Appliances.......................	1,500
	2,650 watts

At 3-wire, 115/230 volts:—2,650÷230 = 11.5 amperes.
No. 10 Conductor recommended (25-amp., 2-pole breaker).

Feeder No. F4

Circuit 13:—Bathroom Heater........................1,000 watts
Circuits 10-12:—Lighting

1,200×2 watts = 2,400 watts
Small Appliances.................. = 1,500
3,900
First 2,500 at 100% = 2,500
1,400 at 30% = 420
3,920 watts

At 3-wire, 115/230 volts:—3,920÷230 = 17 amperes.

No. 10 Conductor recommended (25-amp., 2-pole breaker).

Feeder No. F5

This is a spare for future use (20-amp., 2-pole breaker).

Example.—A typical control center and feeder layout for a single family home is shown in fig. 5,225-9. This home has a floor area of 2,000 square feet and is equipped with such fixed appliances as range, water heaters, dryer, washer, garbage eliminator, etc. The small (or portable) appliance load, such as coffee makers, hand irons, toasters, vacuum cleaners, etc., is taken as 1,500 watts.

Compute the service capacity and minimum feeder sizes when the illumination required is taken as two watts per square foot.

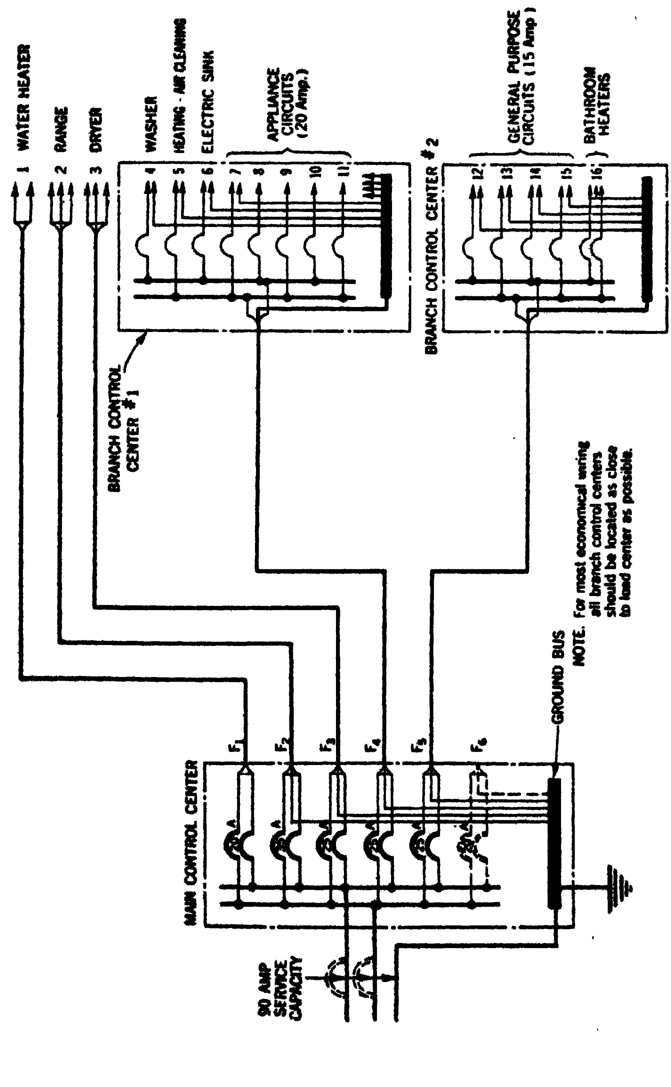


FIG. 5,225-9.—Schematic wiring diagram showing feeder layout for two branch control centers.

Solution.—In a manner similar to the foregoing we obtain:

Service Capacity

General Lighting. 2,000 sq. ft. × 2 watts	= 4,000 watts		
Small Appliances	= 1,500		
	5,500		
	First 2,500	at 100%	= 2,500 watts
	3,000	at 30%	= 900
Range—11,000 watts		Demand	= 7,000
Water Heater	3,000 watts		
Heating-Air Cleaning Unit	900		
Washer	350		
Bathroom Heaters	2,000		
Clothes Dryer	4,500		
Electric Sink (Dishwasher—Garbage Eliminator)	1,000		
	11,750	at 80%	= 9,400
			19,800 watts

Assuming 3-wire, 115/230-volt service:—19,800 ÷ 230 = 86.0 amperes.
No. 2 Conductor required (90-amp., 2-pole breaker).

Feeder No. F1

Circuit 1:—Water Heater .... 3,000 watts
At 2-wire, 230 volts:—3,000 ÷ 230 = 13.0 amperes.
No. 12 Conductor recommended (20-amp., 2-pole breaker).

Feeder No. F2

Circuit 2:—Range .... 7,000 watts
At 3-wire, 115/230 volts:—7,000 ÷ 230 = 30.4 amperes.
No. 8 Conductor required—Neutral No. 10 (35-amp., 2-pole breaker).

Feeder No. F3

Circuit 3:—Clothes Dryer .... 4,500 watts
At 2-wire, 230 volts:—4,500 ÷ 230 = 19.6 amperes.
No. 10 Conductor recommended (25-amp., 2-pole breaker).

Feeder No. F4

Circuit 4:—Washer	350 watts
Circuit 5:—Heating-Air Cleaning Unit	900
Circuit 6:—Electric Sink (Dishwasher—Garbage Eliminator)	1,000
Circuits 7-11:—Small Appliances	1,500
	3,750 watts

At 3-wire, 115/230 volts:—3,750 ÷ 230 = 16.3 amperes.
No. 10 Conductor recommended (25-amp., 2-pole breaker).

Feeder No. F5

Circuit 16:—Bathroom Heaters........................2,000 watts
Circuits 12-15:—Lighting
2,000×2 watts=4,000 watts
Small Appliances..................=1,500
5,500
First 2,500 at 100%=2,500
3,000 at 30%= 900
5,400 watts

At 3-wire, 115/230 volts:—5,400÷230=23.5 amperes.
No. 10 Conductor required (25-amp., 2-pole breaker).

Feeder No. F6

This is a spare for future use (20-amp., 2-pole breaker).

Example.—A wiring layout for a large home is as shown in fig. 5,225-10. The floor area is 3,000 square feet and the illumination required is two watts per square foot. With reference to the diagram there are one main control center and three branch control centers. With the general lighting, fixed and portable appliances as given what will be the minimum service capacity and feeder sizes required in this layout?

Solution.—The feeder capacity is obtained by adding the total wattage and dividing by the voltage in the usual manner. We have:

Service Capacity

General Lighting 3,000 sq. ft.×2 watts=6,000 watts
Small Appliances ....=1,500
7,500
First 2,500 at 100%=2,500 watts
5,000 at 30%=1,500
Range—14,000 watts......................Demand=7,700
Water Heater.......................3,000 watts
Heating-Air Cleaning Unit............1,000
Washer............................ 350
Clothes Dryer......................4,500
Electric Sink (Dishwasher—Garbage Eliminator)......................1,000
Bathroom Heaters—2,400* watts or Air-Cooling Unit—3,100 watts } ..3,100
12,950 at 80%=10,360
22,060 watts

*NOTE.—The larger of these two wattages is used, as it is reasonable to assume that only one of the two units will be in operation at a time.

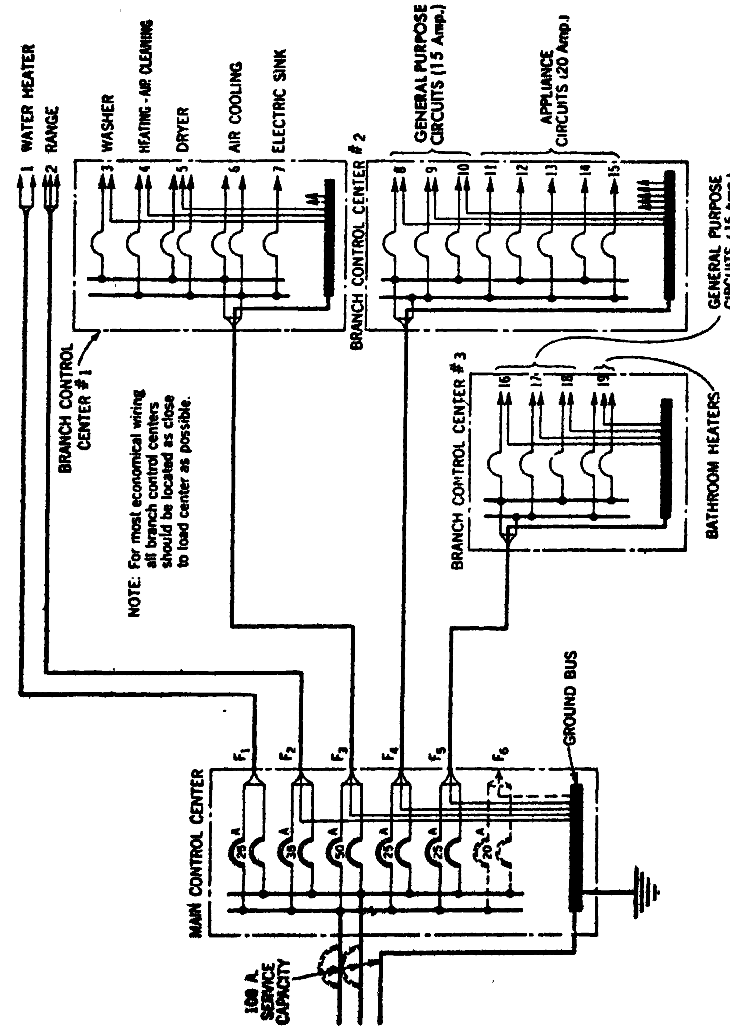


Fig. 5,226-10.—Schematic wiring diagram showing feeder layout for three branch control centers.

Assuming 3-wire, 115/230-volt service:—22,060 ÷ 230 = 95.8 amperes.
No. 1 Conductor required (100-amp., 2-pole breaker).

Feeder No. F1

Circuit 1:—Water Heater .... 3,000 watts
At 2-wire, 230 volts:—3,000 ÷ 230 = 13.0 amperes.
No. 10 Conductor recommended (25-amp., 2-pole breaker). Although No. 12 Conductor (20-amp. breaker) would satisfy this condition, No. 10 Conductor (25-amp. breaker) is recommended for homes in this group.

Feeder No. F2

Circuit 2:—Range .... 7,700 watts
At 3-wire, 115/230 volts:—7,700 ÷ 230 = 33.5 amperes.
No. 8 Conductor required—Neutral No. 10 (35-amp., 2-pole breaker).

Feeder No. F3

Circuit 3:—Washer	350 watts	
Circuit 4:—Heating-Air Cleaning Unit .	1,000	
Circuit 5:—Clothes Dryer	4,500	
Circuit 6:—Air-Cooling Unit	3,100	
Circuit 7:—Electric Sink (Dishwasher—Garbage Eliminator)	1,000	9,950 watts

At 3-wire, 115/230 volts:—9,950 ÷ 230 = 43.3 amperes.
No. 6 Conductor required (50-amp., 2-pole breaker).

Feeder No. F4

Circuits 8-10:—Lighting	*3,000 watts	
Circuits 11-15:—Small Appliances	1,500	
	4,500	
First	2,500 at 100% =	2,500 watts
	2,000 at 30% =	600
		3,100 watts

At 3-wire, 115/230 volts:—3,100 ÷ 230 = 13.5 amperes.
No. 10 Conductor recommended (25-amp., 2-pole breaker).

Feeder No. F5

Circuits 16-18:—Lighting	*3,000 watts	
Small Appliances	1,500	
	4,500	
First	2,500 at 100% =	2,500 watts
	2,000 at 30% =	600
Circuit 19:—Bathroom Heaters		2,400
		5,500 watts

*NOTE.—The total lighting load is 6,000 watts, which, divided over 6 circuits, results in 1,000 watts per circuit. The lighting load per feeder may be arrived at by multiplying the number of circuits by 1,000 watts.

At 3-wire, 115/230 volts:—5,500 ÷ 230 = 23.9 amperes.
No. 10 Conductor required (25-amp., 2-pole breaker).

Feeder No. F6

This is a spare for future use (20-amp., 2-pole breaker).

Meter Connections.—The watthour meter is used to measure the energy consumed in any installation for electric light and power.

A watthour meter in its simplest form consists of a device fundamentally similar to an electric motor; that is, it has one winding which is connected in *series* with the load and the other winding *across* the circuit. The torque of such a meter will, therefore, be proportional to the power and the total revolutions of the meter will be a measure of the energy consumed by the load.

In addition the watthour meter is equipped with a register for recording the revolutions and a magnetic brake. Meter connections for various types of service are shown in figs. 5,225-11 to 5,225-13.

Meter Installations.—Regardless of the number of phases, types of current and voltage, all meters are now manufactured in two classes with respect to their mountings, namely, for:

1. Indoor installations;
2. Outdoor installations.

Meters for indoor installations should in general be mounted securely not less than four feet, nor more than seven feet from the floor in a clean, dry safe place, relatively free from vibration and extremes in temperature.

It is preferable in residential installations that the meters be installed on the ground floor or in the basement. They should not be installed in closets, coal bins, over doors or on insecure partitions, nor in close proximity to machinery, stoves, radiators or steam or gas piping.

Meters designed for outdoor installations are, of course, designed to protect the meter from the weather. A type of meter and meter fittings designed for installation outdoors are shown in figs. 5,225-14 to 5,225-17.

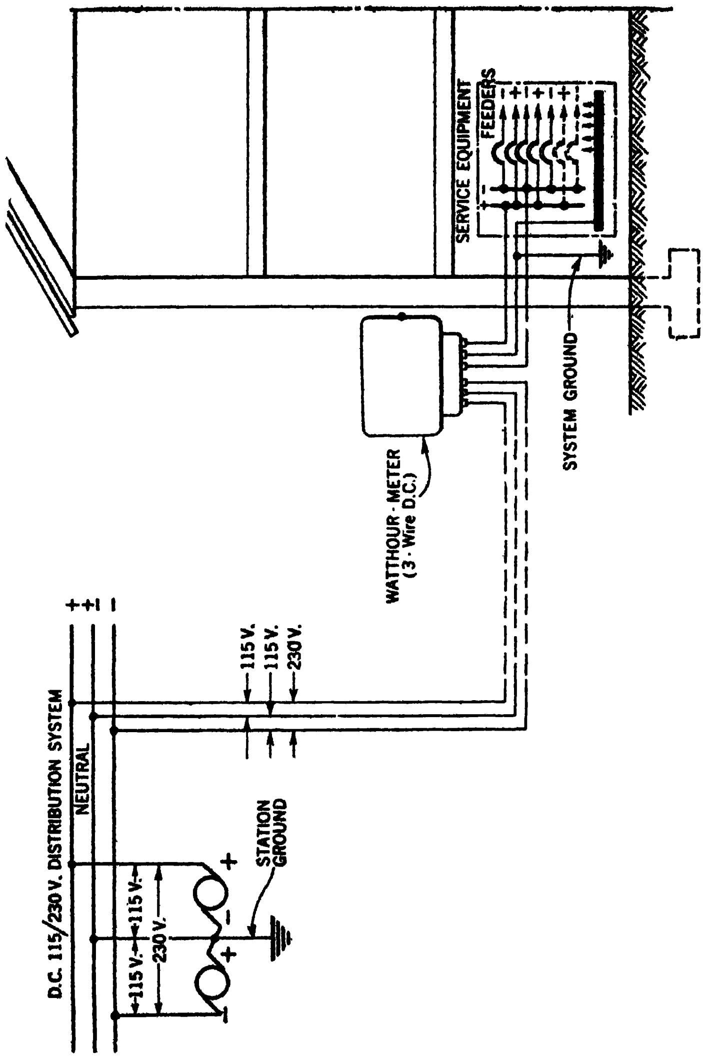


Fig. 5,225-11.—Schematic wiring diagram showing typical feeder layout and watthour meter connection for direct current three-wire service.

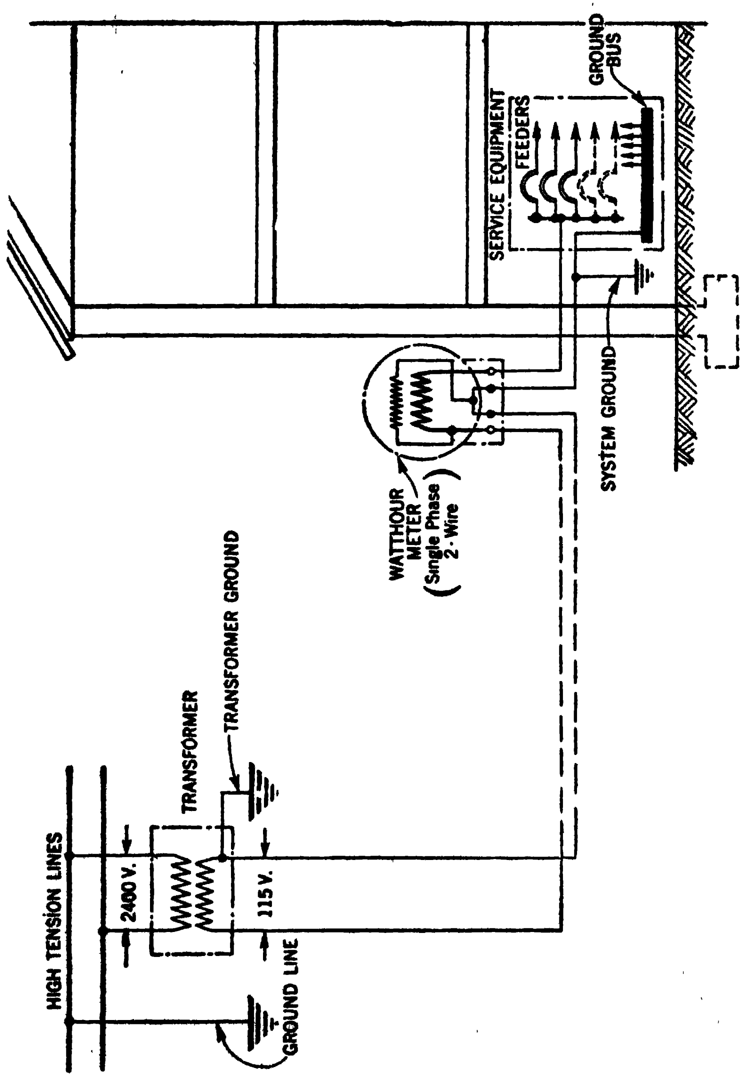


FIG. 5,235 12.—Schematic wiring diagram showing typical feeder layout and watthour meter connection for single phase, two-wire a.c. service.

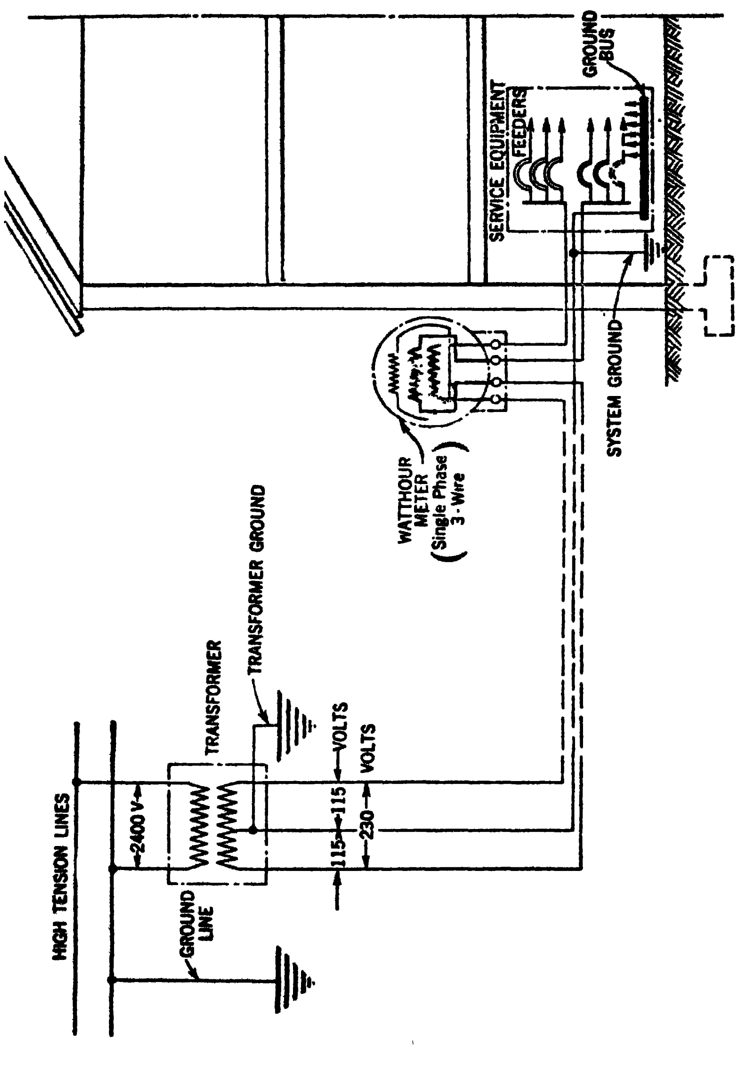


FIG. 5,225-13.—Schematic wiring diagram showing typical feeder layout and watthour meter connection for single phase, three-wire a.c. service.

The detachable type meter provides a most compact installation for outdoor service. It is neat in appearance and can be removed from service instantly for recalibration or checking. A sealing ring is provided to lock the meter into the socket so that it is absolutely tamperproof. As the sealing ring is weatherproof, meters can be installed outdoors without enclosures over them in rural residental areas, but may not be practical in large metropolitan areas or commercial establishments.

Meters located outdoors should in general be mounted at least three feet from the ground or standing level and should be in a location which does not detract appreciably from the appearance of the building. The objections to appearance are largely overcome by selecting inconspicuous locations.

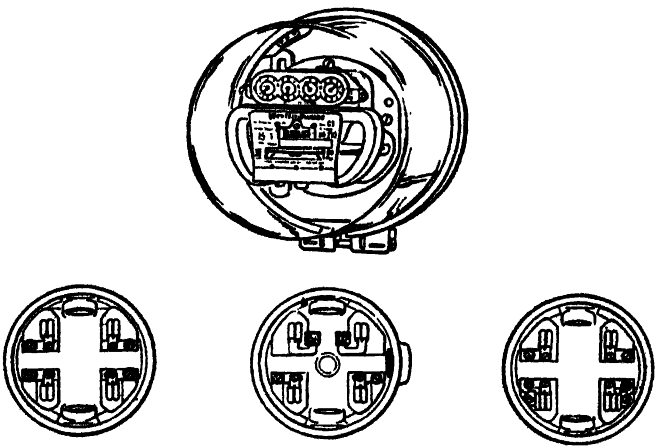


FIG. 5,225-14 to 5,225-17.—Showing Westinghouse type CS detachable watthour meter for outdoor service, with various type sockets.

Grounding.—Interior electrical systems are grounded for the purpose of limiting the voltage upon the system to within the voltage for which the system is designed, or to limit maximum potential to ground due to normal voltage. The system may be exposed to voltage higher than that for which it is designed if supplied through a step-down transformer, in that

there is a possibility of a cross occurring between the primary and secondary lines.

Fig. 5,225-13 shows the conditions normally existing in a grounded three-wire interior wiring system supplied through a transformer from a high tension primary *a.c.* distribution system. The primary is assumed to be single-phase, two-wire with grounded neutral, the voltage being approximately 2,400 volts between the phase wire and the neutral.

In the interior electrical system, the neutral conductor is permanently grounded to a water pipe or direct ground at the service entrance. There is normally no difference of potential between the neutral conductor and any grounded conducting material, such as a cement floor laid directly on the ground or any water pipe. Between any grounded object and either of the ungrounded conductors, there is a difference of potential of nominally 115 volts.

If an accidental connection should occur between the ungrounded high tension conductor and one of the ungrounded secondary conductors, a current will flow from the high tension line to the secondary "hot" (ungrounded) line, through the transformer winding to the grounded secondary conductor, thence to ground and return to the primary system through the grounded neutral of the primary.

The voltage above ground of the interior system will be the voltage drop in the grounding conductor and in the contact between the electrode (such as a pipe or rod driven into the ground) and ground. A good ground to a water system will generally offer a resistance of less than two ohms; a fairly severe condition might result in a current of 100 amperes, and with a resistance of 2 ohms from the neutral conductor to ground, a voltage drop of 200 volts (I×R or 100×2) would result.

On the other hand, if no ground connection was made to the secondary system, then the voltage above ground of the secondary conductors would be very nearly the same as the high tension lines. Not only would this be hazardous to a person accidentally coming in contact with one of the secondary conductors, but the interior electrical system and equipment would be subjected to a severe electrical strain.

As all conducting parts of the interior electrical system are insulated for a normal voltage to ground of not over 600 volts, increasing the potential to 2,400 may cause the insulation to break down in numerous places. From these breakdown points, stray currents may flow to ground and may cause

heating of the conducting material through which it flows to such a high temperature as to cause a fire.

A good effective grounding of the interior electrical system can prevent an excessive increase of the voltage to ground. This will eliminate to a great extent both the hazard to life and the fire hazard, in case of exposure to lightning or through exposure in any other manner of a high potential on the secondary system.

Furthermore, the exposed non-current carrying metal parts of the equipment should be well grounded, thereby keeping them near or at ground potential. Such a precaution will, in case of a breakdown of the insulation of any conductor contained in the equipment (for example the windings of a motor), prevent the exposed metal parts from being raised to a potential much above ground. Therefore, a person touching the equipment will be in no danger of receiving a severe shock.

Fluorescent Lighting Methods

Fluorescent lamps are adaptable to residential interiors for both seeing and decorative purposes because of their shape, coolness and high efficiency. The white and daylight lamps have the greatest application in modern home lighting, while the colored lamps are frequently installed where decorative and architectural lighting is desired.

Nature of Fluorescence.—By definition the *fluorescent lamp* is an electric discharge lamp in which the radiant energy from the electric discharge is transferred by suitable materials (such as phosphorus) into wave lengths giving visible light.

In an incandescent lamp, the light is produced by electricity flowing from one lead wire to another through a filament in the center of the bulb. A fluorescent lamp, on the other hand, has no light-producing filament and its light does not depend on the generation of heat. Here invisible ultraviolet radiation is produced, by an electric discharge through mercury vapor, at low pressure and is converted into visible light through the action of fluorescent substances (phosphorus) which are coated on the inside surface of the tubular lamp.

The coating material used depends upon the color effect desired and may consist of *zinc silicate, calcium tungstate, cadmium borate, zinc beryllium silicate, magnesium tungstate*, etc.

For white and daylight lamps, the foregoing phosphorus are combined. Green, pink and blue lamps use *zinc silicate, cadmium borate* and *calcium tungstate*, respectively. Gold and red lamps use a color phosphorus plus a suitable dye.

All of the phosphorus are chalk-like white powders when not exposed to ultra-violet radiations. Thus the unlighted appearance of most fluorescent lamps are identical. Exceptions are the gold and red lamps in which it is necessary to coat the bulb with the appropriate pigment and then add a second or inner coat of fluorescent powder (*zinc beryllium silicate* and *cadmium borate*, respectively). The pigmented coat absorbs the radiations which are not desired in the spectrum of the finished lamp.

Lamp Construction.—Fluorescent lamps are tubular in shape and are usually provided with special two-pin bases at each end as illustrated in fig. 5,225-18. These pins are connected to the electrodes of the lamp which must be preheated before the lamp is started. They are manufactured in various lengths and wattages ranging from six watts nine inches to 100 watts and 60 inches in length.

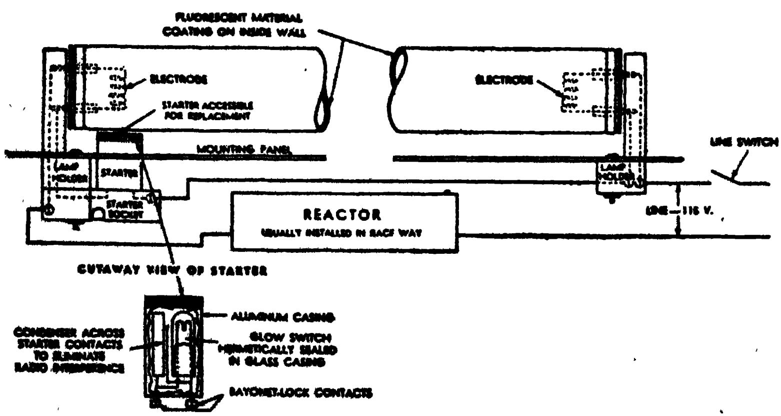


FIG. 5,225-18.—Schematic diagram of typical fluorescent lamp and circuit connections.

Lamp Auxiliaries

The Ballast.—In common with all gaseous discharge lamps, the fluorescent lamp must be provided with some device for limiting the current drawn by the discharge. Without a limiting device, the current would raise to a value that would destroy the lamp. This requirement can best be met by a device or auxiliary called a *ballast.*

The ballast for operating fluorescent lamps on 60 cycle alternating current consists of a small choke coil wound on an iron core.

The ballast serves three important functions, namely:

1. It preheats the electrodes to make available a large supply of free electrons;

2. It provides a surge of relatively large potential to start the arc between the electrodes;

3. It prevents the arc current to increase beyond the limit set for each size of lamp.

The ballast as commonly used is a current limiting device consists of a choke coil alone or in combination with a step-up transformer, as well as condensers for power factor correction. These are usually mounted in the same case as the choke coil, and the entire assembly is insulated in a compound. Thus the entire ballast assembly has only a number of protruding wires which are necessary for making the connections to the external circuit.

Ballasts may be designed for operation of a single lamp or as is more common, for two lamps mounted in a single fixture. Certain practical advantages are obtained from the choice of an electrical circuit which combines under one cover the equipment for the control of two lamps.

Chief among the advantages are improved power factor, decreased stroboscopic effect and reduced auxiliary losses. Each lamp is operated through a separate choke coil. A condenser is connected in series with one lamp and its choke coil to give a leading current. The leading and lagging currents will combine with a resulting line power factor of very nearly 100%.

Starters

A second device necessary with most fluorescent lamps is a *starter*. The starter is designed to act as a time delay switch which will connect the two-filament type electrodes in each end of the lamp in series with the ballast during a short preheating period when the lamp is first turned on and then open the circuit to establish the arc. This preheating causes the emission of electrons from the cathodes and thus makes it possible for the arc to strike without the use of excessively high voltage.

Type of Starters.—The most common type of starter is the *glow type*, although the *thermal* and *manual* types find applications in special circuits such as in direct current circuits and where only a few lights are to be switched such as in home lighting.

Glow-Type Starters.—This is one of the most popular starters used. The switch is enclosed in a small glass bulb, fig. 5,225-19, and consists of two electrodes, one of which is made from a bi-metallic strip, in an inert gas such as neon or argon. These electrodes are separated under normal conditions but when closed form part of a series circuit through the lamp

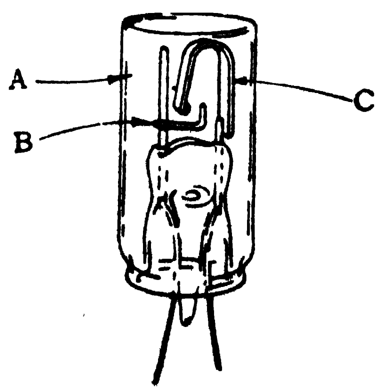


Fig. 5,225-19.—Showing principal parts of typical glow type starter. In the illustration A represents glass bulb filled with inert gas; B, fixed electrode; C, bi-metal strip. It should be observed that one glow type starter is required for each fluorescent lamp.

electrodes and the reactance. When voltage is applied a small current flows as a result of the glow discharge between two electrodes of the switch. Heating of the electrodes results, which by the expansion of the bi-metallic element, causes the electrodes to touch. This short circuiting of the switch stops the glow discharge but allows a substantial flow of current to preheat the lamp electrodes.

There is enough residual heat in the switch to keep it closed for a short period of time for the electrode preheating. The glow being quenched, the bi-metal cools, the switch opens and the resultant high voltage surge starts normal lamp operation. If the lamp arc fails to strike, the cycle is repeated.

Thermal Starters.—A typical thermal or resistance-heat-operated starter is shown in fig. 5,225-20. In a starter of this type, when the line switch is closed, the bi-metal operating strip **A** is touching carbon contact **B**, thus allowing the current to preheat the lamp cathodes. However, the heat generated by the current at this point of contact causes the bi-metal **A** to move away from **B**, thus establishing an arc within the lamp. **A** is then kept away from **B** by heat generated in resistor **C**, which is subjected to the same voltage as the lamp.

In re-starting, after a momentary interruption of current, **C** is subjected to full-line voltage, and the additional heat causes **A** to bend until it touches restart contact **D**. This allows current to preheat the cathodes again; but at the same time, it short-circuits **C**, so that **A** moves away from **D** and an arc is established again.

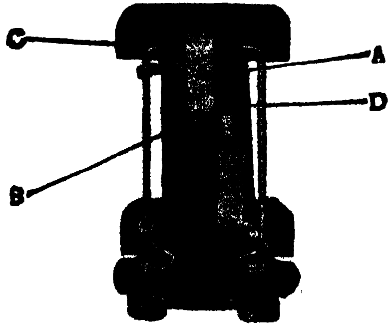


FIG. 5,225-20.—Showing essential parts of a thermal type starter.

Manual Starters.—The simplest type of starter is the manual type. In its basic form it consists of a switch or push button connected in series with the two cathodes (electrodes) of the lamp. To start the lamp the line switch must first be turned on. The starter switch is then closed until the electrodes have become heated. This takes only a few seconds. Then the starter switch is opened to establish the arc. A small condenser connected across the terminals of the starter reduces arcing, and also aids in the elimination of radio interference during the starting and the operating periods.

Frequently, in manual-type starters, the line switch and starter switch are incorporated in a single unit. Push-button switches of this type are so designed that the starter switch is closed when the button is fully depressed. The chief advantage of the manual type starter is its simplicity. The inconvenience of operation, however, makes it suitable only for applications where relatively few lamps are involved. Its use has been confined almost entirely to desk and portable lamps and similar applications where the lamp itself is within easy reach.

Lamp Circuit Ballasts

When connecting lamps, ballast and starter into an electric circuit, it is of the utmost importance to observe the manufacturer's diagram usually labeled on the ballast. This diagram should be followed in each instance for proper operation of the lamp or lamps. Also it should be clearly understood that each lamp size must have a ballast designed for its particular wattage, potential and frequency.

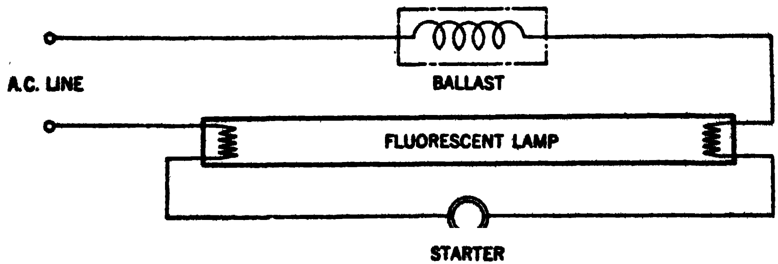


FIG. 5,225-21.—Wiring diagram showing essential elements and wiring of single fluorescent lamp. Due to the absence of power factor corrective element (condenser) any *a.c.* lamp connected in this manner will have a lagging power factor.

Diagrams figs. 5,225-21 to 5,225-27 are intended to illustrate the various types of ballast circuits, but it should be noted that the exact relationship of these parts and the manner in which the wires are brought out from the case may differ for the ballasts of different manufacturers.

Single-Lamp Ballasts.—The circuit for the single lamp ballasts is shown in fig. 5,225-21, whereas a power factor corrected ballast is shown in fig. 5,225-22. For operating the 13, 30, 40 and 100 watt lamps on 110-125 volt circuits, the ballast must include a transformer for stepping up the voltage. In single lamp power factor corrected ballasts of this type, a condenser as shown by the dotted lines, fig. 5,225-23, must be included.

Two-Lamp Ballasts.—These are designed to provide power factor correction and also to minimize *stroboscopic effect**.

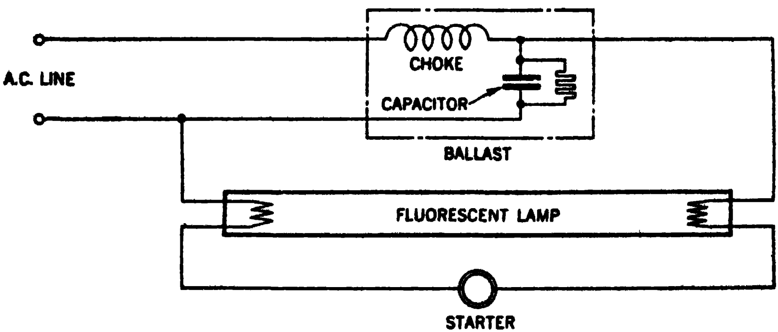


Fig. 5,225-22.—Wiring diagram of single fluorescent lamp with power factor corrected ballast.

They actually include two separate choke coils, one of which has a condenser in series with it to accomplish the desired power factor correction. This is possible because of the fact that a condenser produces what is known as a *leading* power factor which offsets the *lagging* power factor caused by the inductive choke.

It is in this manner that the power factor of fluorescent lamp circuits are adjusted to nearly unity in most cases. It is customary to term that lamp which is connected to the condenser side of the ballast as the *leading lamp*, and that connected to the inductive coil or choke, as the *lagging lamp*. Figs. 5,225-24 to 5,225-27 show typical connection methods.

*NOTE.—The stroboscopic effect is an effect giving the illusion of a changing motion of movable objects when exposed to rapid light pulsations such as that generated by an alternating current.

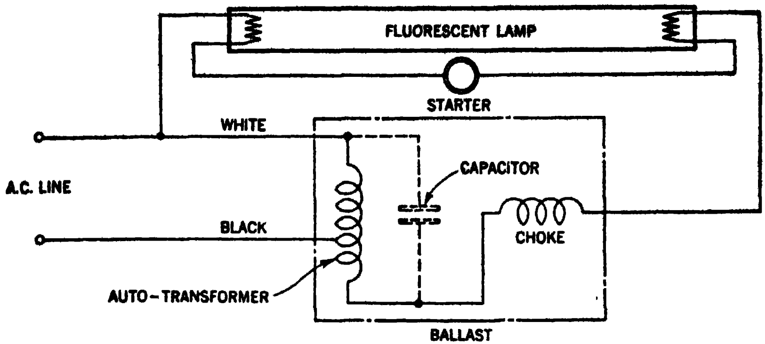


FIG. 5,225-23.—Wiring diagram of single fluorescent lamp with power factor corrected ballast and auto-transformer.

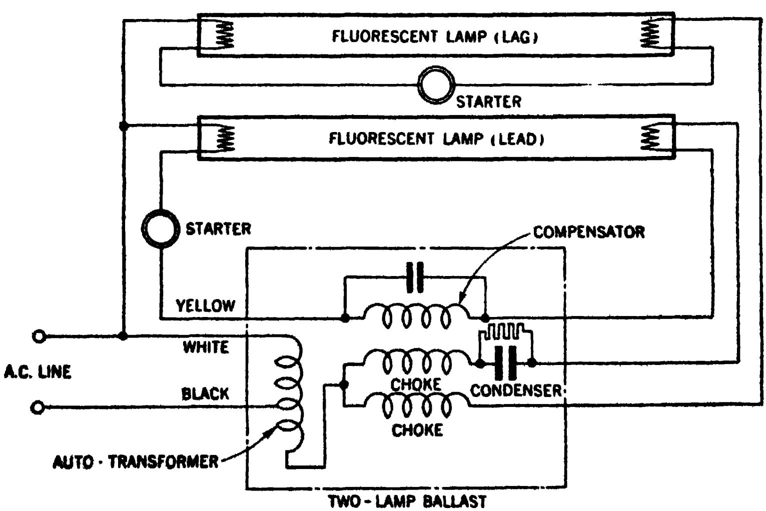


FIG. 5,225-24.—Wiring diagram of two-lamp ballast with built-in starting compensator and auto-transformer.

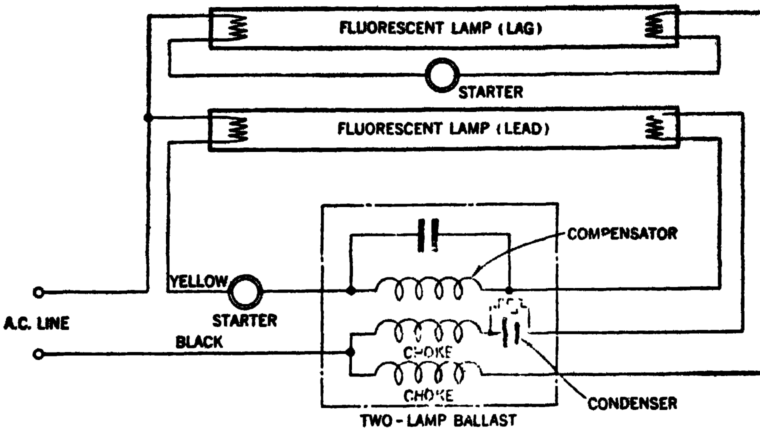


FIG. 5,225-25.—Wiring diagram of two-lamp ballast with built-in starting compensator.

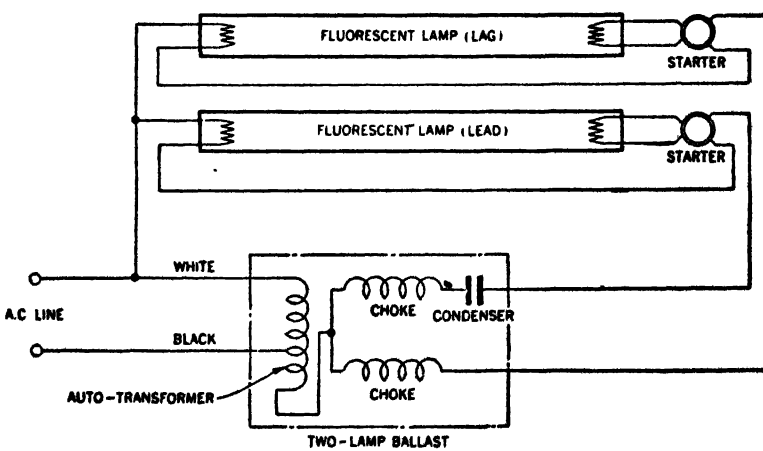


FIG. 5,225-26.—Wiring diagram of a two-lamp ballast with a four-contact starter socket for each lamp.

Lampholders and Starter Sockets.—These are usually available for lamps with miniature, medium and mogul bipin bases. Usually the starter is mounted separately so that it may readily be replaced without removing the lamp itself. A standard twist-turn type of lampholder is shown in fig. 5,225-28, while a starter and separate socket is shown in fig. 5,225-29.

Mogul starter sockets have four contacts and hence there are four leads coming from a socket of this type. See fig. 5,225-26. When a combination mogul lamp holder and starter socket is used, the connections between the two are already made internally.

Direct Current Operation.—While the fluorescent lamp is basically an alternating current lamp, it is also used on *d.c.* service when *a.c.* is not available. When operated on *d.c.* only about 80% of *a.c.* life performance can be expected.

Also on *d.c.* the extra wattage loss in the resistance ballast is considerably larger than the *a.c.* ballast loss, thus causing a less economical operation.

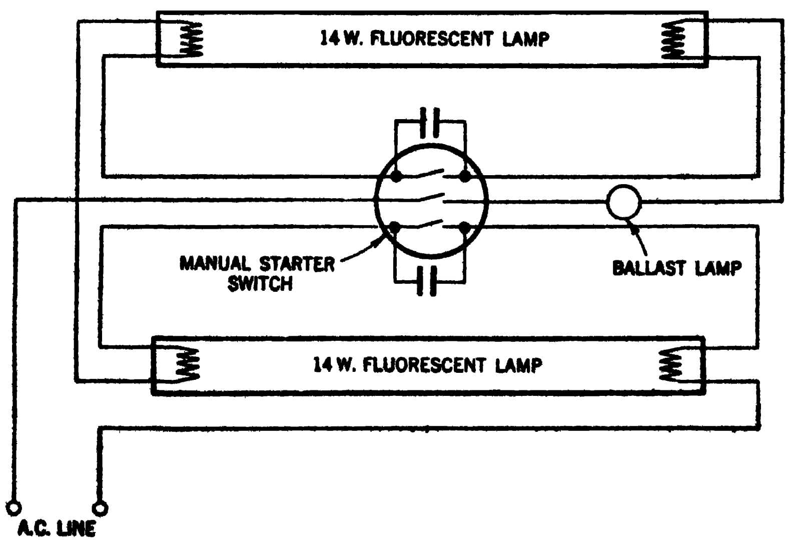
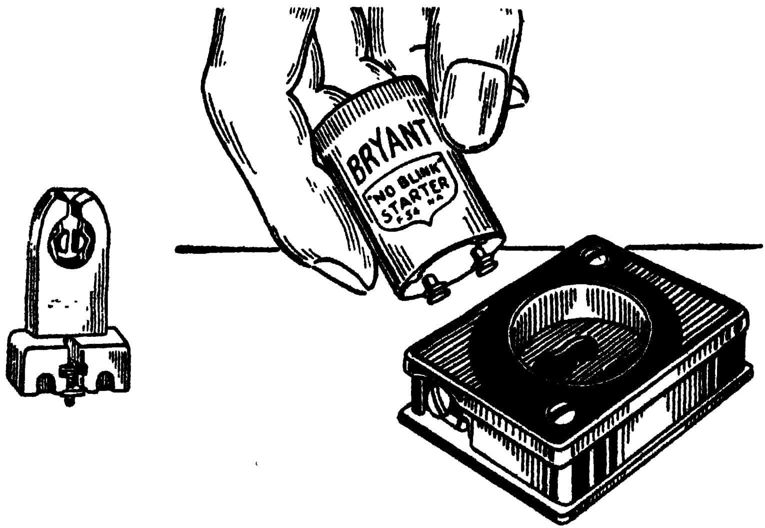


FIG. 5,225-27.—Wiring diagram for operating two 14 watt fluorescent lamps in series with a

Due to the lack of voltage peak where *d.c.* is used, lamp starting is generally more difficult than on *a.c.* and special starting devices should be used. The thermal and manual starting switches in addition to a starting inductance are generally employed. Ordinarily the glow switch is not suitable for *d.c.* operation and although no harm will result, the lamp generally will not start.

With fluorescent lamps, one end of the tube may become dim after operating a few hours on *d.c.* due to the bombardment of the electrons in one direction only. By reversing the direction of current flow at certain intervals (once a day or more frequently if desired) by means of a special



Figs. 5,225-28 and 5,225-29.—Showing a standard twist-turn lampholder for fluorescent lamps with medium bipin bases and fluorescent lamp starter and starter socket.

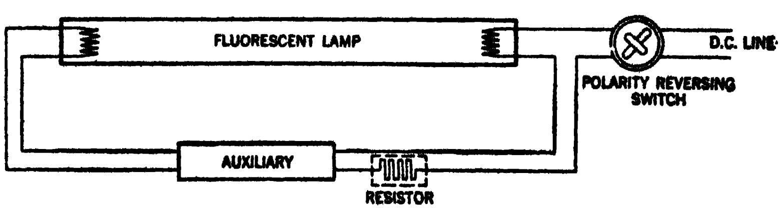


Fig. 5,225-30.—Wiring diagram of fluorescent lamp for operation on direct current.

polarity reversing switch, this end dimming may be eliminated. Fig. 5,225-30 shows a general wiring diagram of the fluorescent lamp and necessary circuit elements for *d.c.* operation.

TEST QUESTIONS

1. *What does an effective and efficient electrical system depend upon?*
2. *What is generally understood by the terms (a) fixed appliances, and (b) portable appliances?*
3. *What are the three fundamental rules which must be followed if the lighting of the home is to be truly good?*
4. *What factors should be considered in choosing the fixture for a home?*
5. *What are the three essential components in a fluorescent fixture?*
6. *Where should the entrance light be placed in a home?*
7. *What is the most important room in the home with reference to lighting?*
8. *What is the minimum requirements with reference to the number of convenient outlets?*
9. *What are the two requisites for a well lighted kitchen?*
10. *Give the purpose and general location of the master control switch in a home.*
11. *What is the smallest size conductor recommended for use in wiring the home?*
12. *Why is it customary to place the control centers near the load center when wiring a home?*
13. *How are the number and size of control centers usually determined?*
14. *What are the two steps in the process of determining the maximum load that feeders and entrance conductors will be required to carry?*

15. *Name the five components composing the service entrance in a home wiring system.*
16. *Where is the watthour meter usually located in a home wiring system?*
17. *Name the three principal methods employed in calculating illumination requirements in a home.*
18. *What is the minimum illumination requirements in watts per square foot in single and multi-family dwellings?*
19. *Draw a schematic wiring diagram giving sequence of apparatus and circuit breakers for a two-branch control center.*
20. *Draw a schematic wiring diagram showing typical feeder layout and watthour meter connections for a single phase, three wire a.c. service.*
21. *What is the purpose of grounding interior electrical systems?*
22. *What types of fluorescent lamps have their greatest application in modern home lighting?*
23. *What is the function of the ballast as applied to a fluorescent lamp?*
24. *What is the function of the starter and how does it operate in a fluorescent lamp circuit?*
25. *Name three types of fluorescent type starters and give the construction of each.*
26. *What method is employed in correcting the power factor of fluorescent lamps?*
27. *Draw a wiring diagram of a two-lamp ballast with starting compensator and starter.*

CHAPTER 97

Wires and Wire Calculations

To acquaint the reader with the terminology employed in this and subsequent chapters, the following definition of terms most commonly used are given:

Appliance.—Appliances are current consuming equipment, fixed or portable for example, heating, cooking and small motor operated equipment.

Branch Circuit.—That portion of a wiring system extending beyond the final overcurrent device protecting the circuit. A device not approved for branch circuit protection, such as a thermal cutout or motor overload protective device, is not considered as the overcurrent device protecting the circuit.

Branch Circuits (Appliance).—Appliance branch circuits are circuits supplying energy either to permanently wired appliances or attachment plug receptacles, that is, appliance or convenience outlets or to a combination of permanently wired appliances and additional attachment plug outlets on the same circuit; such circuits to have no permanently connected lighting fixtures.

Branch Circuits (Combination Lighting and Appliance).—Combination lighting and appliance branch circuits are circuits supplying energy to both lighting outlets and appliance outlets.

Branch Circuits (Lighting).—Lighting branch circuits are circuits supplying energy to lighting outlets only.

Branch Circuits (Motor).—A motor branch circuit is a branch circuit supplying energy only to motors.

Cabinet.—A cabinet is an enclosure designed either for surface or flush mounting and provided with a frame, mat or trim in which swinging doors are hung.

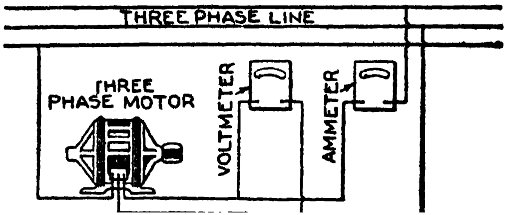


Fig. 6,868.—Three phase motor test; voltmeter and ammeter method. If it be desired to determine the approximate load on a three phase motor, this may be done by means of the connections as shown in the figure, and the current through one of the three lines and the voltage across the phase measured. If the voltage be approximately the rated voltage of the motor and the amperes the rated current of the motor (as noted on the name plate) it may be assumed that the motor is carrying approximately full load. If, on the other hand, the amperes show much in excess of full load rating, the motor is carrying an overload. The heat generated in the copper varies as the square of the current. That generated in the iron varies anywhere from the 1.6 power, to the square. This method is very convenient if a wattmeter be not available, although, it is, of course, of no value for the determination of the efficiency or power factor of the apparatus. This method gives fairly accurate results, providing the load on the three phases of the motor be fairly well balanced. If there be much difference, however, in the voltage of the three phases, the ammeter should be switched from one circuit to another, and the current measured in each phase. If the motor be very lightly loaded and the voltage of the different phases vary by 2 or 3 per cent., the current in the three legs of the circuit will vary 20 to 30 per cent.

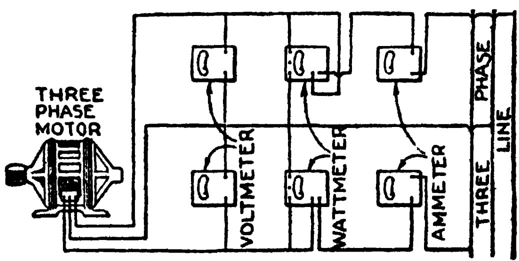


Fig. 6,869.—Three phase motor test by the two wattmeter method. If an accurate test of a three phase motor be required, it is necessary to use the method here indicated. Assume the motor to be loaded with a brake so that its output can be determined. This method gives correct results even with considerable unbalancing in the voltages of the three phases. With the connections as shown, the sum of the two wattmeter readings gives the total power in the circuit. Neither meter by itself measures the power in any one of the three phases. In fact, with light load one of the meters will probably give a negative reading, and it will then be necessary to either reverse its current or pressure leads in order that the deflection may be noted. In such cases the algebraic sums of the two readings must be taken.. In other words, if one read plus 500 watts and the other minus 300 watts. the total power in the circuit will be 500 minus 300, or 200 watts. As the load comes on, the readings of the instrument which gave the negative deflection will decrease until the reading drops to zero, and it will then be necessary to again reverse the pressure leads on this wattmeter. Thereafter the readings of both instruments will be positive, and the numerical sum of the two should be taken as the measurement of the load. If one set of the instruments be removed from the circuit, the reading of the remaining wattmeter will have no meaning. As stated above, it will not indicate the power under these conditions in any one phase of the circuit. The power factor is obtained by dividing the actual watts input by the product of the average of the voltmeter readings × the average of the ampere readings × 1.73.

Conduit Box.—A conduit box is a metal box adapted for connection to conduit for the purpose of facilitating wiring, making connections, mounting devices, etc.

Distribution Center.—A distribution center is a point at which is located equipment consisting generally of automatic overload protective devices connected to buses, the principal functions of which are the subdivision of supply and the control and protection of feeders, sub-feeders or branch circuits or any combination of feeders, sub-feeders or branch circuits.

Distribution Center (Branch Circuit).—A branch circuit distribution center at which branch circuits are supplied.

Distribution Center (Feeder).—A feeder distribution center is a distribution center at which feeders or sub-feeders are supplied.

Distribution Center (Main).—A main distribution center is a distribution center supplied directly by mains.

Feeder.—A feeder or feeder circuit is a conductor or group of conductors of a wiring system between the service equipment or the generator switchboard of an isolated plant, and the branch circuit overcurrent device.

A feeder or feeder circuit in an interior wiring system, is a set of conductors extending from the original source of energy in the installation to a distributing center and having no other circuits connected to it between the source and the center.

Sub-Feeder.—A sub-feeder is an extension of a feeder, or of another sub-feeder, from one distribution center to another and having no other circuit connected to it between the two distribution centers.

Junction Box.—A junction box is a metal box with a blank cover which serves the purpose of joining different runs of conduit, tubing wireway or raceway, and provides space for the connection and branching of the enclosed conductors.

Knockout.—A knockout is a portion of the wall of a box or cabinet so fashioned that it may be removed readily by the blow of a hammer at the time of installation in order to provide a hole, usually circular in shape for the entrance of wires or the attachment of conduit, cable, etc.

Mains.—A main is any supply circuit to which other consuming circuits, sub-mains or branches, are connected through automatic cutouts (fuses or circuit breakers) at different locations along its length. An energy consuming device is never connected directly to a main, a cutout is always being interposed between the device and the main.

Mains (Interior Wiring).—Mains are the conductors extending from the service switch, generator bus or converter bus to the main distribution center.

Service Conductors.—That portion of the supply conductors which extends from the street main or duct or from transformers to the service equipment of the premises supplied. For overhead conductors this includes the conductors from the last line pole to the service equipment.

Service Equipment.—The necessary equipment, usually consisting of circuit breaker or switch and fuses and their accessories located near the point of entrance of supply conductors to a building and intended to constitute the main control and means of cutoff for the supply to that building.

Service (Master).—A master service is a service supplying the service equipment which supplies a group of buildings under one management.

Pull Box.—A pull box is a metal box with a blank cover which is inserted in a run of conduit, raceway or tubing to facilitate pulling in the conductors, or which is installed at the termination of one or more runs of conduit, raceway tubing or wireway for the purpose of distributing the conductors.

Direct Current Wiring

By direct current wiring we generally mean a system of wiring in which the current flowing in the wires is supplied by means of *direct current generators*, *rectifiers* or *batteries*.

Direct current although occasionally found as a source of power and light in industrial plants is not used to any large extent except for electric railroad operation where the third rail system of power distribution is being used. Other locations where direct current has found employment is in metal refinery and electroplating processes and also in certain industries where close regulation of motor speed is required.

The possibility of obtaining a wide range of speed adjustment and maintenance of nearly constant speed relations makes the direct current motor useful particularly in reversing steel mill drives and other locations where close speed regulation is necessary.

Wiring Systems.—There are two wiring systems in general use for direct current work. They are:

1. Two wire, and
2. Three wire systems.

The source of electrical supply may be a central or an isolated plant. The greater part of interior wiring is done on the two-wire system, the three-wire system being used primarily for feeders and mains.

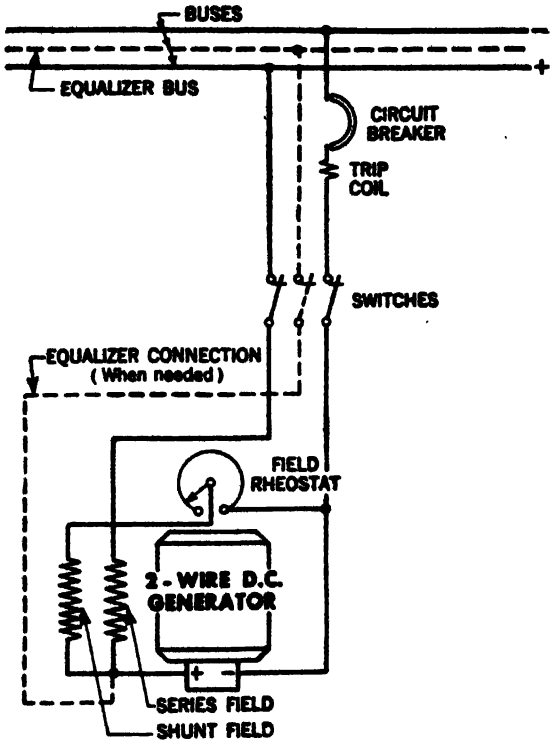


FIG. 6,870.—Typical connection diagram of two-wire direct current generator protected by a single pole circuit breaker.

Direct current three-wire systems usually employ a three-wire generator with an external balance coil, although instead of one balance coil two such coils are sometimes used. In a system of

this type the center tapped balance coil or coils act as a neutral and is therefore usually referred to as the *neutral* or *third* wire..

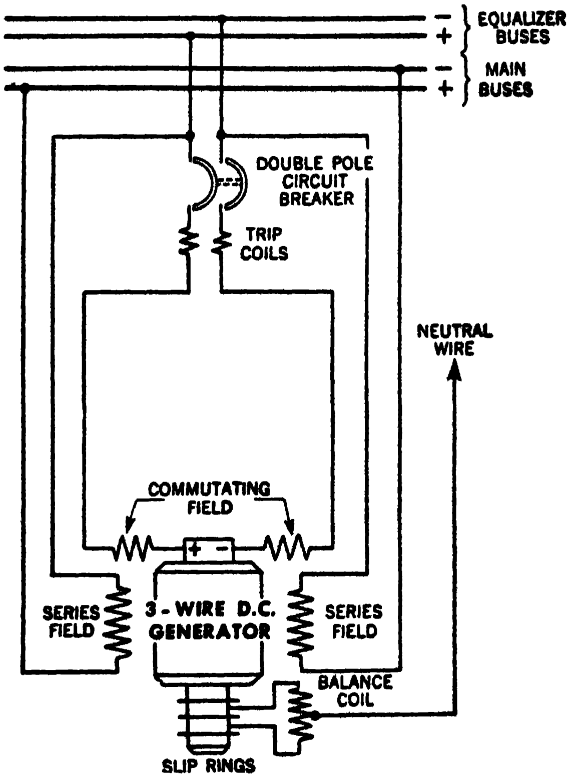


FIG. 6,871.—Typical connection diagram for three-wire generator having one balance coil and a double-pole, double-coil circuit breaker.

With the direct current three wire system, the neutral wire is generally made of the same size as either of the two outer wires. The reason for having the three wires of the system of the same size is because if one of the outer fuses should burn out, one side

of the system would be loaded while the other wire would have no current flowing. Where a grounded neutral has the same area or cross section as either of the outer wires, the fuse is generally omitted.

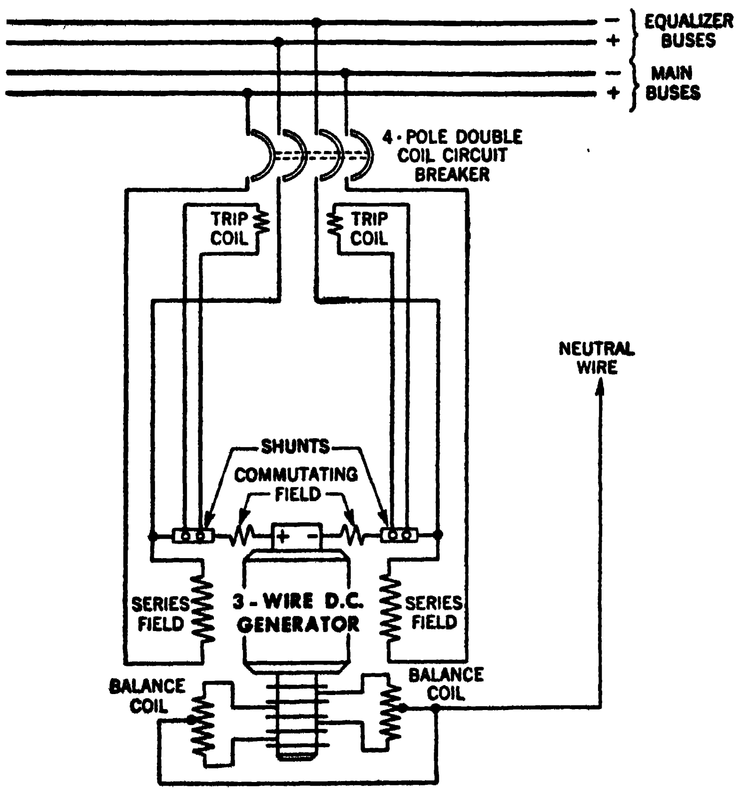


Fig. 6,872.—Typical connection diagram for three-wire generator having two balance coils and a four-pole two-coil circuit breaker.

When designing a three-wire distribution system some effort should be made to arrange the load so that the unbalanced current be kept at a minimum, and in any event not to exceed 25% of the full load current flowing

in the outer wires. Motors unless very small, are generally connected across the outer wires, and will therefore receive approximately twice the voltage of the lamps, which are connected across one of the outer wires and the neutral.

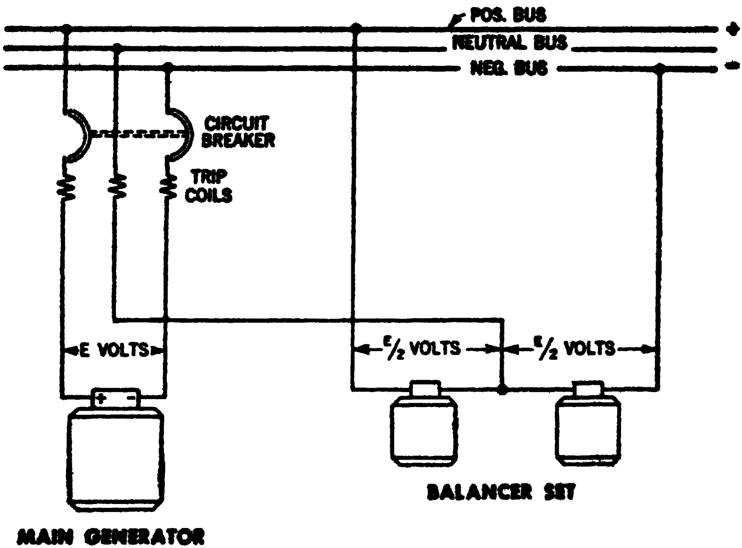


FIG. 6,873.—Typical connection diagram of balancer set operated in connection with a two-wire generator to supply a three-wire direct current system. On a balanced load both machines constituting the balancer set run *light* as motors, but with an unbalanced load one machine runs as a motor, thus driving the other machine which runs as a generator, since they are both mechanically as well as electrically connected. According to *Code requirements*, two wire generators used in conjunction with balancer sets to obtain neutrals for three-wire systems shall be equipped with overcurrent devices which will disconnect the three-wire system in the case of excessive unbalancing of voltages.

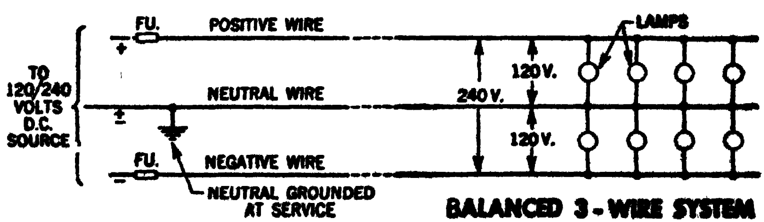


FIG. 6,874.—Three-wire direct current system of distribution. When the same number of lamps of equal size be connected in the manner shown, there will be no current flow in the neutral wire.

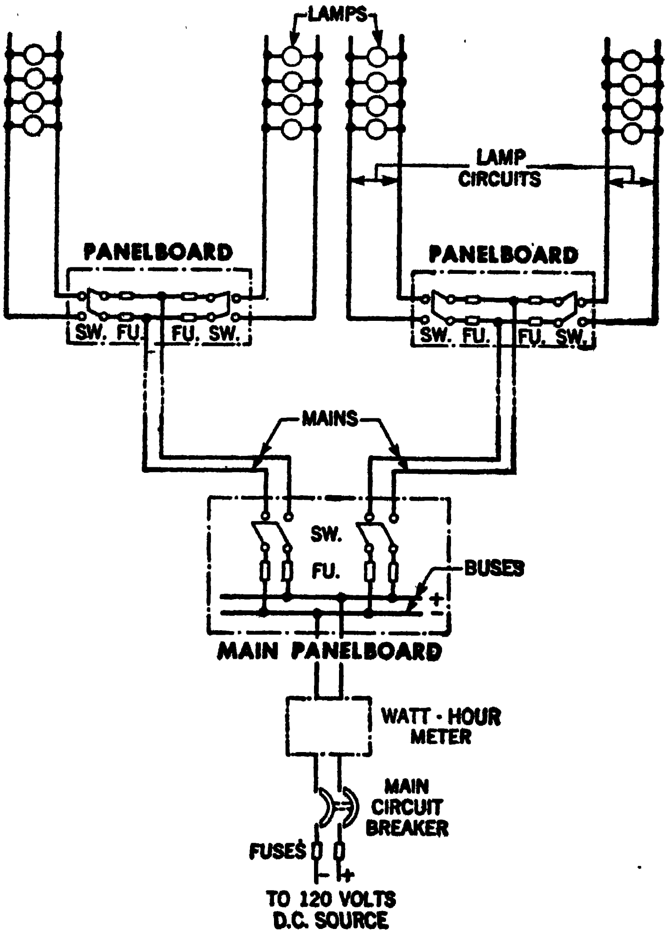


FIG. 6,275.—Showing general scheme of wiring for two-wire system.

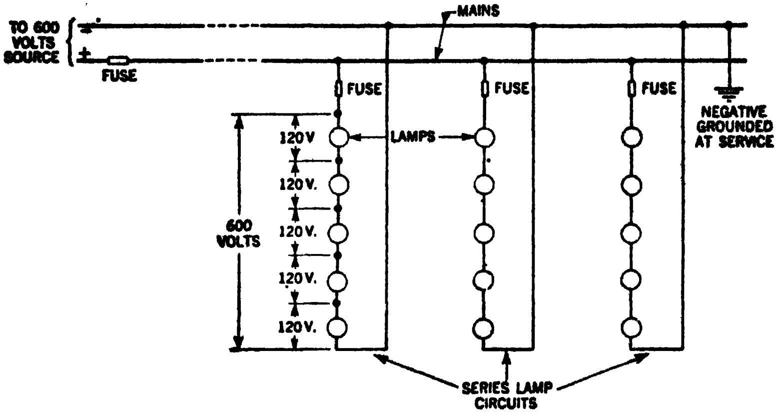


FIG. 6,876.—Series lamp system of distribution. A system of this type is used for lighting chiefly in certain railroad operations where the lamps are connected directly between the third rail and negative conductor. The difference in pressure between any two points in the circuit is equal to the lamp voltage, (about 120 volts) multiplied by the number of lamps in the circuit. The obvious disadvantage in using a system of distribution of this sort is that if one filament burns out the whole circuit will fail (since all lamps are connected in series) in addition if the circuit becomes grounded between any one of the lamps, the lamps will receive an excessive voltage usually ending in failure of the filament or filaments.

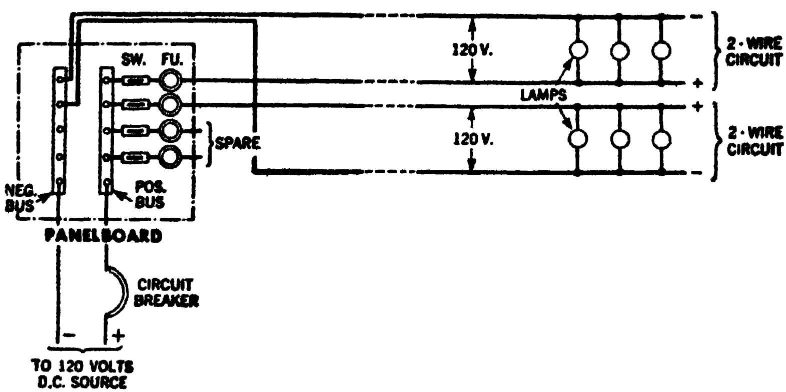


FIG. 6,877.—Showing typical lamp connection to a distribution panel supplied from a two-wire direct current source.

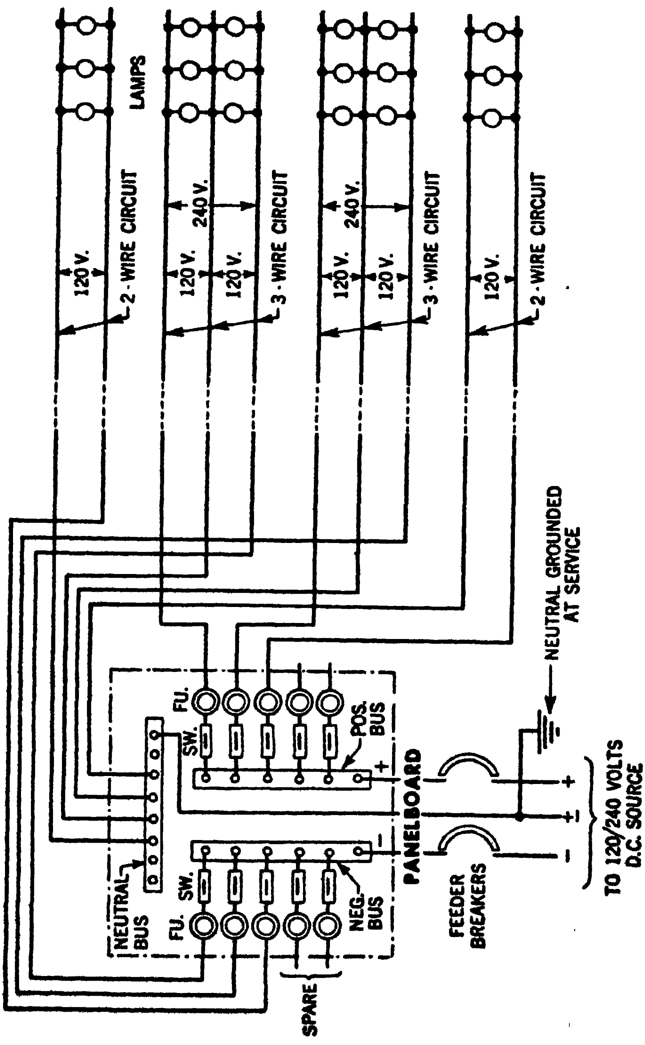


FIG. 6,878.—Showing typical lamp connection to a distribution panel, supplied from a three-wire direct current source. In a three-wire distribution system of this type, the load should be balanced as closely as possible between the two outer wires and the neutral.

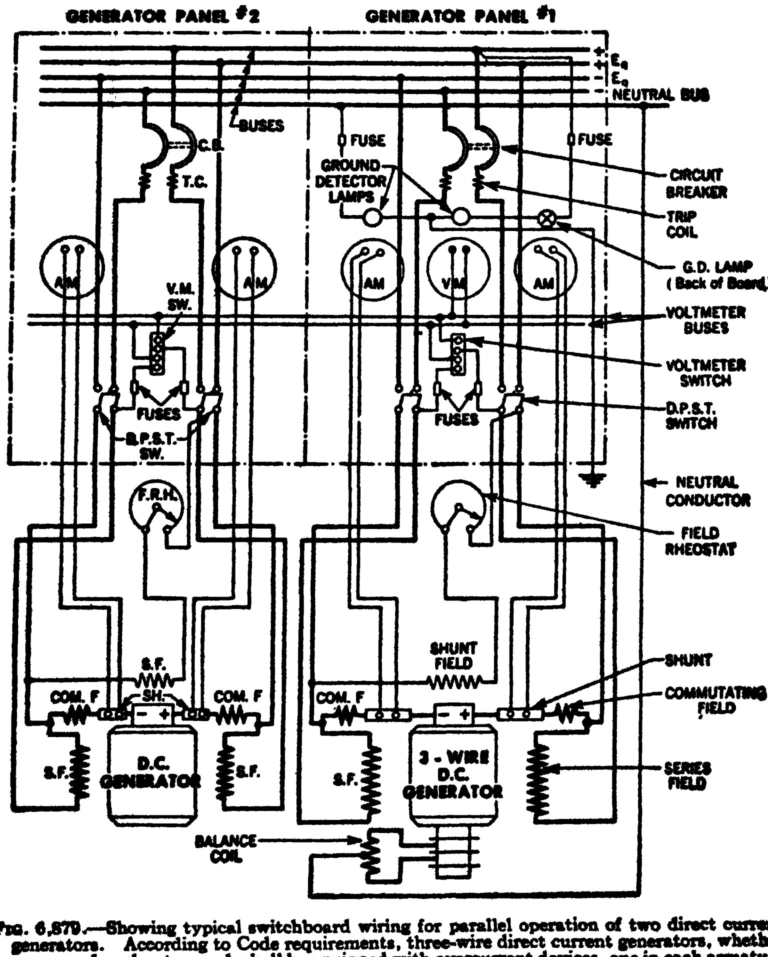


FIG. 6,879.—Showing typical switchboard wiring for parallel operation of two direct current generators. According to Code requirements, three-wire direct current generators, whether compound or shunt wound, shall be equipped with overcurrent devices, one in each armature lead, and so connected as to be actuated by the entire current from the armature. Such overcurrent devices shall consist either of a double-pole, double-coil circuit breaker, or of a four-pole circuit breaker connected in the main and equalizer leads and tripped by two overcurrent devices, one in each armature lead. Such protective devices shall be so interlocked that no one pole can be opened without simultaneously disconnecting both leads of the armature from the system.

Load Center.—The load center of a circuit is that point at which it can be assumed that the total load is concentrated. Thus the load center of a group of equally spaced motors or lamps each of the same size will be at the middle of that group as shown in fig. 6,880.

To determine the load center of a group of appliances of unequal size and spacing proceed as follows:

1. Multiply the current taken by each appliance by its distance to the point of distribution or mains.
2. Add all the products thus found and divide this sum by the total current of the circuit.

A typical example showing the method used for determination of the load center of a circuit is shown in fig. 6,881.

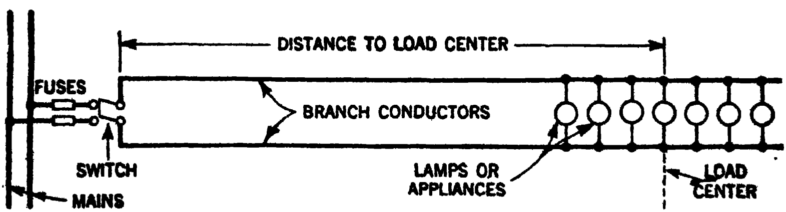


FIG. 6,880.—Showing load center of equally spaced lamps or appliances all of which have the same capacity or current demand.

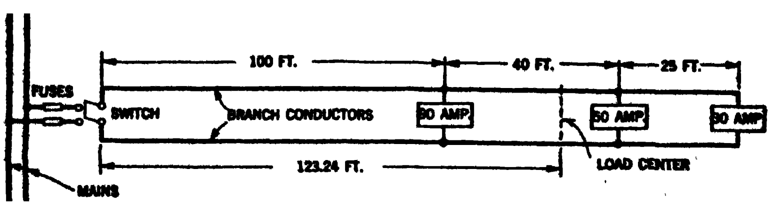


FIG. 6,881.—Illustrating method of calculating load center distance of a circuit having unequal loads unsymmetrically spaced. With reference to text calculation for the above circuit is as follows: Number of ampere feet for the complete load = 100 × 90 + 140 × 50 + 165 × 30 = 20,950. The total amperage of the circuit = 90 + 50 + 30 or 170. The distance in feet from the switch terminal = 20,950/170 or 123.24 feet.

Conductor Economy.—In interior and exterior wiring installations it is often necessary to increase the conductor size beyond that which is required by the *National Electrical Code* because of economical considerations. Obviously any conductor selected for a particular installation must fulfill the requirements of mechanical strength and carrying capacity and the voltage drop must not exceed practical limits.

In most cases one of the foregoing requirements will determine the size of the conductor. It may be well, however, also to consider the power loss (I^2R) which calculation may indicate that it will be desirable to use a larger conductor than contemplated because of the cost of the power wasted due to the excessive resistance in the conductor.

It has been laid down as a general rule, that for the transmission of any given amount of energy, the most economical conductor is one having such a resistance that the value of the energy wasted in heat annually is equal to the interest per annum on the original outlay upon the conductor. This rule is known *Kelvin's Law*. This law is also frequently stated as follows: *The most economical cross-section of a conductor is that for which the annual cost of energy wasted is equal to the interest on that portion of the capital outlay, which can be considered proportional to the weight of copper used.*

Stated mathematically the cross-section of the most economical conductor is:

$$A = 593I \sqrt{\frac{c_1 x h}{c \times p}} \quad \text{circular mils} \qquad (1)$$

Where I = current in amperes for (h) hours per year.
c_1 = cost of electrical energy in dollars per KWH.
c = cost of wire in dollars per pound.
p = annual percent interest on capital invested in line wires, including depreciation and taxes.

Wiring Calculation.—Because of its favorable electrical and mechanical characteristics *copper* is nearly always used as a conductor for both exterior and interior wiring. Every conductor offers a certain amount of resistance to the flow of current and this resistance varies directly as the length of the conductor, and inversely as its cross-sectional area.

Therefore, if a length of a conductor be known and its cross-sectional area as well as the conductivity of the material, its resistance may easily be calculated. Accordingly, the resistance of any conductor is equal to its *length in feet* multiplied by its *resistance per mil foot*, thus:

$$\text{Resistance in ohms} = \frac{\text{Length in feet} \times \text{Resistance per mil foot.}}{\text{Circular mils}}$$

$$\text{or briefly, Ohms} = \frac{\text{Feet} \times 10.8^*}{\text{Circular mils}} \qquad (2)$$

If letters be used, we obtain the customary formula for a two wire circuit:

$$R = \frac{L \times 21.6}{A} \qquad (3)$$

Where R = resistance in ohms.

L = Length one way or the single distance of the circuit in feet.

A = cross-sectional area of conductor in circular mils.

*NOTE 1.—The resistance of a circular mil foot of commercial copper (a wire one foot in length having a cross-sectional area of one circular mil) is usually quoted at from 10.6 to 11 ohms per mil foot at normal temperatures. For practical wiring calculations 10.8 ohms per mil foot is sufficiently accurate to give an acceptable result.

NOTE 2.—In countries where the meter system is being used, the resistance value for commercial copper is quoted as 0.0175 ohm per meter, when the cross-sectional area of the conductor is one square millimeter. The formula for resistance in ohms of a single conductor then becomes:

$$R = \frac{\text{Length in meters} \times 0.0175}{\text{Area in square millimeters}}$$

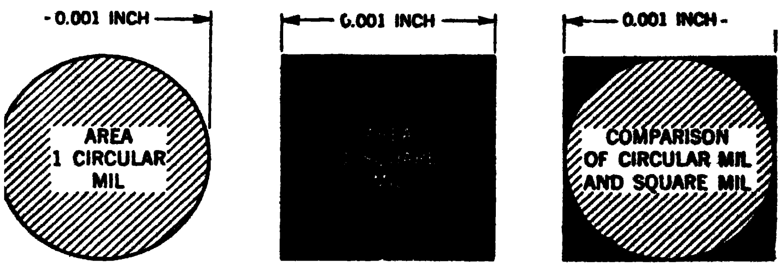
For a complete circuit, we obtain:

$$R = \frac{2 \times \text{Length in meters} \times 0.0175}{\text{Area in square millimeters}}$$

Effect of Resistance.—The effect of resistance to an electric current is to cause a drop in voltage, and the energy lost in overcoming this resistance appears in the form of heat. Now, according to Ohm's law,

$$\text{Volts} = \text{Amperes} \times \text{Ohms} \tag{4}$$

With the assistance of the foregoing expression the voltage drop in any direct current circuit may readily be obtained. Thus, for example, if the circuit carries a current of 200-*amp*. and the total resistance be say 0.035 ohm, the voltage drop $= 200 \times 0.035$ or 7 volts.



FIGS. 6,882 to 6,884.—Showing greatly enlarged views of circular mil and square mil. Fig. 6,884 indicates relative size of the two units.

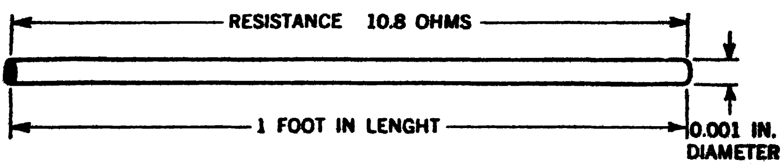


FIG. 6,885.—Illustrating dimensions and approximate resistance of one circular mil-foot of copper.

By substituting in (4) the value for the resistance in ohms as obtained in (2) we have

$$\text{Volts} = \frac{\text{Amperes} \times \text{Feet} \times 10.8}{\text{Circular mils}} \tag{5}$$

If the customary symbols be used, we may write,

$$E = \frac{I \times L \times 10.8}{A} \qquad (6)$$

Where E is the voltage drop, I the current in amperes and A the cross-section of the conductor in circular mils.

In the foregoing formula therefore E means that the volts lost, or drop between the beginning and the end of a circuit is equal to the current flowing through the circuit multiplied by the product of the conductors' length in feet, multiplied by the resistance of one mil foot of wire, divided by the area of the conductor in circular mils.

Since the length of the circuit is given as the "run" or distance one way, that is, one half the total length of wire in the circuit, formula (6) must be multiplied by 2 to get the total drop, therefore we may write:

$$E = \frac{I \times L \times 2 \times 10.8}{A} = \frac{I \times L \times 21.6}{A} \qquad (7)$$

If equation (7) be solved with respect to the wire size in circular mils, we have

$$A = \frac{I \times L \times 21.6}{E} \qquad (8)$$

Similarly $I = \dfrac{E \times A}{21.6 \times L}$ (9)

and $L = \dfrac{E \times A}{21.6 \times I}$ (10)

Where it is desired to have a working formula for N lamps each of which requires I amperes, we obtain

$$A = \frac{21.6N \times I \times L}{E} \tag{11}$$

If on the other hand, it is desired to find the number of lamps which a given size of wire will supply with a given voltage drop, another formula may be written as follows,

$$N = \frac{A \times E}{21.6 \times L \times I} \tag{12}$$

It should be remembered that all of the foregoing formulas apply to direct current heating appliance and lamp circuits only. In the case of calculations for direct current motors, the formulas should include provision for overload current and efficiency of motor as determined by the *National Electrical Code.*

Power Loss Calculation.—If it be assumed that 10.8 ohm is the resistance of a circular mil foot of copper wire, the power loss in watts in any electrical copper conductor may be found thus:

$$P = \frac{10.8 \times I^2 \times L}{A} \tag{13}$$

Where P is the power loss in the conductor in watts

I is the current in amperes flowing in the conductor.

L is the length of the conductor in feet (one way).

A is the area of the conductor in circular mils.

For a two wire direct current circuit, we have:

$$P = \frac{21.6 \times I^2 \times L}{A} \tag{14}$$

Where the resistance of circuit is given, the power loss in watts may be obtained from the expression:

$$\text{Power loss in watts} = I^2R \tag{15}$$

Direct Current Motor Circuit Calculation.—With respect to direct current motors, the Code requires each motor to have a name plate with the name of the manufacturer, capacity in volts, current in amperes, horsepower ratings and the normal speed in revolutions per minute, etc. In calculating for such motors it is only necessary to take the efficiency of the motor and the overload into consideration to arrive at an acceptable value for the required wire size.

The formula for the size of wire in circular mils necessary for a direct current motor rated in horsepower will therefore be as follows:

$$A = \frac{HP \times 746 \times L \times 21.6 \times 1.25}{E \times E_t \times \text{efficiency}} \qquad (16)$$

Where HP is the rating in horsepower of the motor; L, distance in feet to the motor; E, voltage drop; E_t terminal voltage. The overload factor is here taken as 1.25 since branch circuit conductors supplying an individual motor must have a carrying capacity not less than 125 percent of the motor's full load current rating. For long runs, it may be necessary in order to avoid excessive voltage drop to use conductors of sizes larger than obtained by the foregoing formula.

Calculations of direct current circuits may be made directly from the foregoing formulas, although in practice, voltage drop tables and curves are usually resorted to in designing of conductor sizes. The following examples will serve to illustrate calculation procedures.

***Example.**—A copper transmission line* 1.5 *miles in length is used to transmit* 10 *kilowatts from a* 600 *volt generating station. The voltage drop in the line is not to exceed* 10% *of the generating station voltage.*

Calculate

(*a*) Line current.

(*b*) Resistance of the line.

(*c*) Cross-section of wire.

Solution.—(*a*) Line current $I_L = \dfrac{10{,}000}{600} = 16.67$ amp. *Ans.*

Voltage drop $= 600 \times 0.1 = 60$ volts.

(*b*) Resistance of the line $= \dfrac{60}{16.67} = 3.6$ ohms. *Ans.*

Substituting the foregoing values in formula (3) we obtain

$$3.6 = \frac{5{,}280 \times 2 \times 1.5 \times 10.8}{A} \text{ or}$$

$$(c)\ A = \frac{5{,}280 \times 3 \times 10.8}{3.6} = 47{,}520 \text{ C.M.} \quad \textit{Ans.}$$

The nearest size of wire having an area equal to or greater than this is a No. 3 wire and this should be used. (See table page 3,073).

Example.—*A certain wiring scheme requires a circuit 50 feet in length which is to be made up of a No. 10 wire. The current is 35 amperes. Calculate the voltage drop in the circuit.*

Solution.—Substituting the values in formula (7) we obtain:

$$E = \frac{35 \times 50 \times 21.6}{10{,}380} = 3.6 \text{ volts.} \quad \textit{Ans.}$$

Example.—*What size wire should be used on a 250-volt circuit to transmit a current of 200 amperes a distance of 350 feet to a center of distribution, with a loss not to exceed 3% under full load?*

Solution.—Substituting the given values in formula (8) we obtain,

$$A = \frac{200 \times 350 \times 21.6}{0.03 \times 250} = 201{,}600 \text{ C.M.} \quad \textit{Ans.}$$

The nearest size conductor having an area equal to or larger than this is a 0000 conductor.

Example.—*A two-wire circuit is to carry a load of 50 amperes a distance of 300 feet with a permissible voltage drop of 2.5 volts. What size of conductor must be used?*

Solution.—Substituting our values in formula (8) we obtain,

$$A = \frac{50 \times 300 \times 21.6}{2.5} = 129{,}600 \text{ C.M.} \quad \textit{Ans.}$$

ma nearest size conductor having an area equal to or larger than this is a W.G. which should be used.

***Example.**—It is desired to connect 80, 50-watt incandescent lamps on a 110 volt circuit. The distance from the mains to the center of the lamp group is 200 feet. What size wire is required if a maximum voltage drop of two volts be permitted?*

Solution.—Since each lamp takes 50 watts, the current flow is $50 \times {}^{80}/_{110}$ or 36.36 amperes. Substituting the given values in formula (8) the size of wire is found to be:

$$A = \frac{21.6 \times 36.36 \times 200}{2} = 78{,}538 \text{ C.M.} \quad \textit{Ans.}$$

The nearest size of wire having an area equal to or greater than this is a No. 1, and this should be used.

***Example.**—A combined lamp and heating appliance load requires 70 kilowatts. The distance between the load center and the distributor panel is 250 feet. The voltage at the distribution panel is 230 volt and it is desired to keep the voltage drop within 2%. What size conductor is required?*

Solution.—The current flow is 70,000/230 or 304.3 amperes. Applying formula (8) the size of the conductor is found to be

$$A = \frac{304.3 \times 250 \times 21.6}{0.02 \times 230} = 357{,}550 \text{ C.M.} \quad \textit{Ans.}$$

The nearest size of conductor having an area equal to or greater than this is a 400,000 circular mil cable.

***Example.**—A 20 kilowatt balanced lighting load is to be supplied by a three-wire 115/230 volts generator. The length of the run between the generator switchboard mains and the lighting load center is 250 feet. What size of conductor should be used if maximum voltage drop permitted is 2%?*

Solution.—On a balanced three-wire system the current in each of the outer conductors would be 20,000/230 or 87 amperes. The permissible voltage drop is 0.02×230 or 4.6 volts. Substituting our values in formula (8) the conductor size is found to be

$$A = \frac{87 \times 250 \times 21.6}{4.6} = 102{,}130 \text{ C.M.} \quad \textit{Ans.}$$

The nearest size conductor having the required area is No. 1/0, since No. 1 conductor has an area of only 83,690 circular mils.

***Example.**—It is required to calculate the voltage drops on an unbalanced direct current three-wire circuit having the following data: Length of circuit 750 feet; Positive and negative conductor each No. 000 A.W.G. Neutral conductor No. 1 A.W.G. The positive and negative conductor carries 125 and 100 amperes respectively.*

Solution.—With reference to table giving properties of copper conductors (page 3,073) we obtain the resistance of 1,000 feet of No. 000 = 0.0642 ohm and that of No. 1 = 0.129 ohm per 1,000 feet.

The respective voltage drops are calculated as follows:

$$E = IR = 125 \times 0.0642 \times 0.75 = 6.02 \text{ volts}$$
(drop on positive conductor).

$$E = IR = 100 \times 0.0642 \times 0.75 = 4.82 \text{ volts}$$
(drop on negative conductor).

$$E = IR = (125 - 100)\ 0.129 \times 0.75 = 2.42 \text{ volts}$$
(drop on neutral conductor).

In a voltage drop calculation of this type the voltage drop in the neutral conductor is added to the drop on the side having the larger current and subtracted from the side having the smaller current, thus making the total voltage drop 6.02 + 2.42 = 8.44 volts on the "heavy" side, and 4.82 — 2.42 = 2.40 volts on the "lighter" side. *Ans.*

Example.—*Calculate the conductor size required to connect a direct current motor rated at 50 amperes, when the supply voltage is 230, the circuit length is 50 feet and the voltage drop 4 volts.*

Solution.—By applying formula (8) we obtain

$$A = \frac{50 \times 50 \times 21.6}{4} = 13{,}500 \text{ C.M.} \quad \textit{Ans.}$$

Since a No. 10 conductor contains only 10,380 circular mils the next larger size or a No. 8 conductor should be used.

Example.—*What is the approximate number of amperes drawn by a 30 horsepower direct current motor having an efficiency of 90% when connected to a 230 volts source?*

Solution.—The current drawn by the motor is

$$I = \frac{\text{Horsepower} \times 746}{\text{Impressed voltage} \times \text{Efficiency}} = \frac{30 \times 746}{230 \times 0.9} = 108 \text{ amperes.}$$

Example.—*A 25-h.p. 230-volt d.c. motor is to be supplied with power from a switchboard bus located at a distance of 75 feet from the motor. The line drop is not to exceed 5% of the receiver voltage, when the motor is delivering full load at 86% efficiency.*

Calculate

(*a*) *Cross-section area of feeder in C.M.*

(*b*) *Kilowatts supplied to switchboard.*

Solution.—The current drawn by the motor is

$$I = \frac{25 \times 746}{230 \times 0.86} = 94.3 \text{ amperes.}$$

The voltage drop in the conductors

$$E = 0.05 \times 230 = 11.5 \text{ volts.}$$

(*a*) Cross-sectional area of conductors

$$A = \frac{94.3 \times 75 \times 21.6}{11.5} = 13{,}300 \text{ C.M.} \quad \textit{Ans.}$$

(*b*) Power supplied at switchboard

$$Ps = \frac{94.3 \times 241.5}{1{,}000} = 22.77 \text{ kilowatts.} \quad \textit{Ans.}$$

Example.—*Determine the power loss in a circuit 80 feet in length consisting of No. 1 conductors when the current density is 75 amperes.*

Solution.—Applying formula (14) the power loss is,

$$P = \frac{21.6 \times 75^2 \times 80}{83{,}690} = 116 \text{ watts}$$

Example.—*What size wire should be used for a 20 horsepower 220-volt motor having an efficiency of 90% when the length of the circuit is 80 feet and the drop 2 volts?*

Solution.—Applying formula (16) with proper constants, we obtain,

$$A = \frac{20 \times 746 \times 80 \times 21.6 \times 1.25}{220 \times 2 \times 0.9} = 81{,}400 \text{ C.M.}$$

The nearest standard size conductor is a No. 1 A.W.G. which has an area of 83,690 circular mils.

Example.—*What is the proper size of wire for a 10-h.p., 220-volt motor having an efficiency of 90% when the length of the circuit is 200 feet and the maximum allowable voltage drop is 2%?*

Solution.—Substituting the given values in formula (16) we obtain,

$$A = \frac{10 \times 746 \times 200 \times 21.6 \times 1.25}{220 \times 4.4 \times 0.9} = 46{,}240 \text{ C.M.}$$

The nearest size conductor having an area equal to or larger than this is a No. 3 conductor and this should be used.

Alternating Current Wiring

Alternating current wiring differs from that of direct current mainly in certain effects which must be considered and which do not enter into direct current calculations. They are:

1. Inductance { Self-inductance / Mutual-inductance.
2. Capacity.
3. Skin effect.
4. Frequency.
5. Power factor.

For interior wiring where incandescent lamps are fed by an alternating current, none of the foregoing factors needs consideration, since mutual inductance, capacity and skin effect are so small as to be almost negligible. Therefore, in lamp wiring the previously given formulas may be applied to alternating current as well.

Self-Inductance.—Self-inductance is the property of an electric circuit which determines, for a given rate of current change in the circuit, the electromotive force induced in the same circuit.

Mutual Inductance.—Mutual inductance is the common property of two associated electric circuits which determines for a given rate of current change in one of the circuits, the electromotive force induced in the other.

Capacity.—In a system of more than two conductors a voltage difference between them corresponds to the presence of a quantity of electricity in each. All alternating current circuits have a certain capacity because each conductor acts like the plate of a condenser, and the insulating medium acts as a dielectric. The capacity between two or more conductors depends upon the insulation of each

Skin Effect.—Skin effect is the phenomenon of non-uniform current distribution over the cross-section of a conductor caused by the variation of the current in the conductor itself. The tendency of an alternating current to confine itself to the outer portions of the conductor has the effect of increasing its ohmic resistance.

If the conductor be large, or the frequency high, the central portion of the conductor carries little if any current, hence the resistance of a conductor is greater for alternating current than for direct current.

Frequency.—The frequency of an alternating current in ordinary light and power circuits depends upon the construction of the generator (number of poles) and the revolutions per minute (speed of the machine). In the United States the commercial frequency is usually 60 cycles per second, although certain power systems are designed for 25 and 50 c.p.s. The number of cycles per second has a direct effect upon the inductance of the circuit.

Power Factor.—The power factor is the *ratio* of *active power* to *apparent power*. Where the load consists of incandescent lamps only, the power factor is unity or one hundred per cent. In all alternating current circuits having an inductive load, such as fluorescent lamps and motors, allowance must be made for the power factor because of the inductive characteristic of this type of load.

Voltage Drop (Lighting Load Only).—The maximum voltage drop to the lamp in a well designed lighting system, should *not exceed three per cent.* Many designs limit the drop to two per cent or less. If, on the other hand, the illumination is not used for work, and if economy demands it, voltage drops of five per cent or more, may have to be allowed.

The fluctuations at the service and the additional lowering of the service voltage due to regulation of the service transformers (where employed) by any connected motor loads to the same transformers must also be taken into account when deciding the maximum value of the permissible voltage drop.

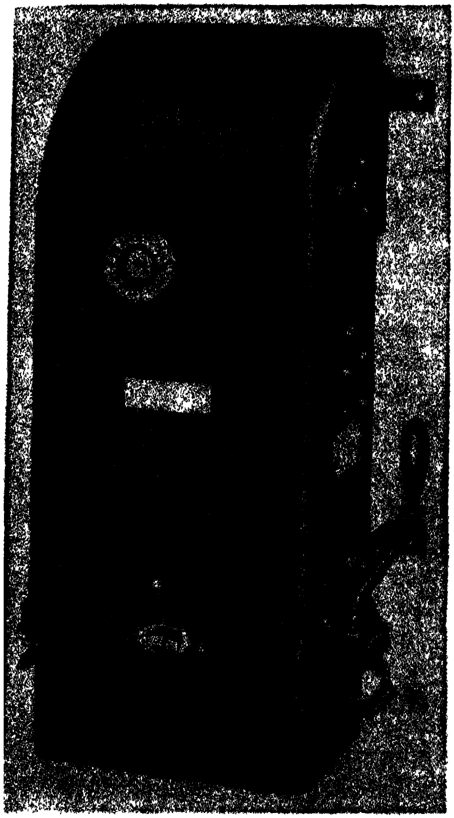


FIG. 6,886.—General Electric *a.c.* reduced voltage autotransformer type starter for squirrel cage induction motors. This compensator consists principally of an autotransformer, a manually operated set of contacts, and a temperature overload relay.

Voltage Drop (A.C. Motors Only).—For feeders serving power loads only it is necessary to consider the behavior of the alternating current motor at reduced voltages. Roughly, the full-load current of an induction motor varies inversely with the

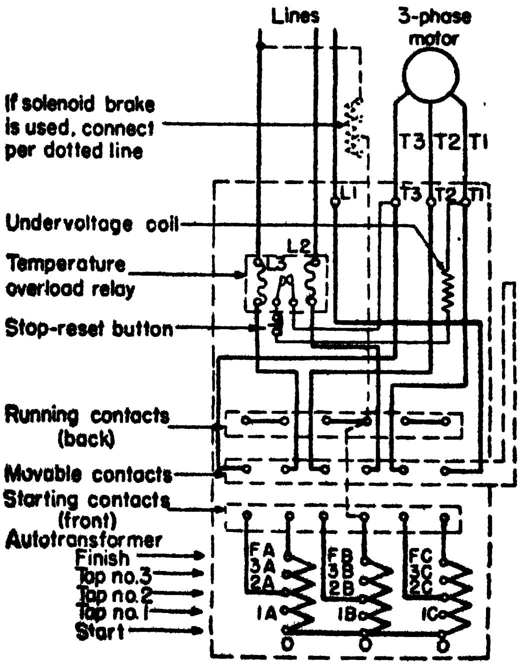


FIG. 6,887.—Wiring diagram of General Electric a.c. reduced voltage autotransformer type starter for squirrel cage induction motors. *Operation:* With reference to fig. 6,886, when the operating handle is pushed away from the operator, the autotransformer is connected to the power source, and at the same time, the motor which is being controlled is connected to the taps of the autotransformer. These taps apply a certain percentage of the line voltage to the motor. After the motor speed has reached a normal value, the operator pulls back the handle to the running position, which connects the motor to full line voltage. The handle is held in the running position by an under-voltage tripcoil. If the overload relay trips out, if the line voltage fails momentarily, or if the cover is removed, the under-voltage coil is de-energised and this allows the handle to return to the off position. To restart the motor, the overload relay must be reset by pushing a reset button on the outside of the case. Then the operating handle is thrown first to the starting then to the running position to start the motor.

voltage; both the starting torque and the pull-out torque vary directly with the square of the voltage; the slip at a given load varies about inversely with the square of the voltage.

The reduction of terminal voltage at the motor has very little effect on the speed; it increases the current (and thereby the calculated voltage drop also) and considerably reduces the starting and pull-out torques. Where these torques are not of prime importance, as with fan and pump drives, the values of voltage

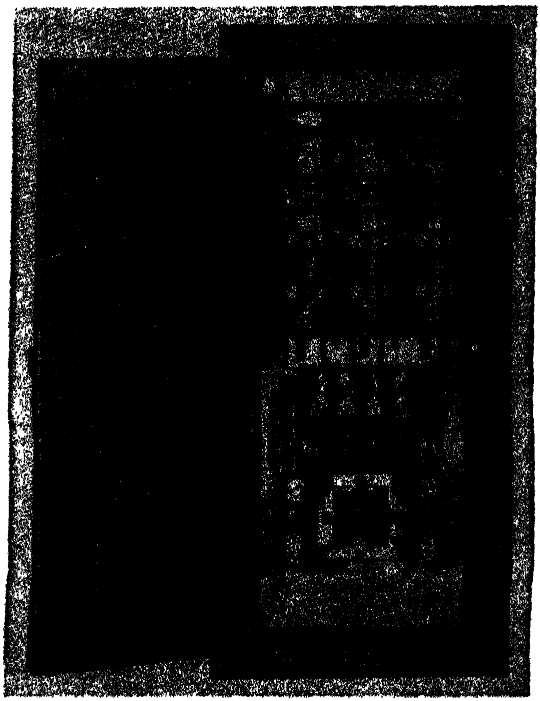


FIG. 6,888.—Combination *a.c.* magnetic motor starter with cover open. The cover of the starter is so interlocked with the safety switch handle that the cover cannot be opened when the safety switch is in the *on* position, nor can the safety switch be closed when the cover is open. This arrangement provides protection for the motor maintenance man or operator.—*Courtesy General Electric Co.*

drop within certain limits is mostly subject to economic consideration.

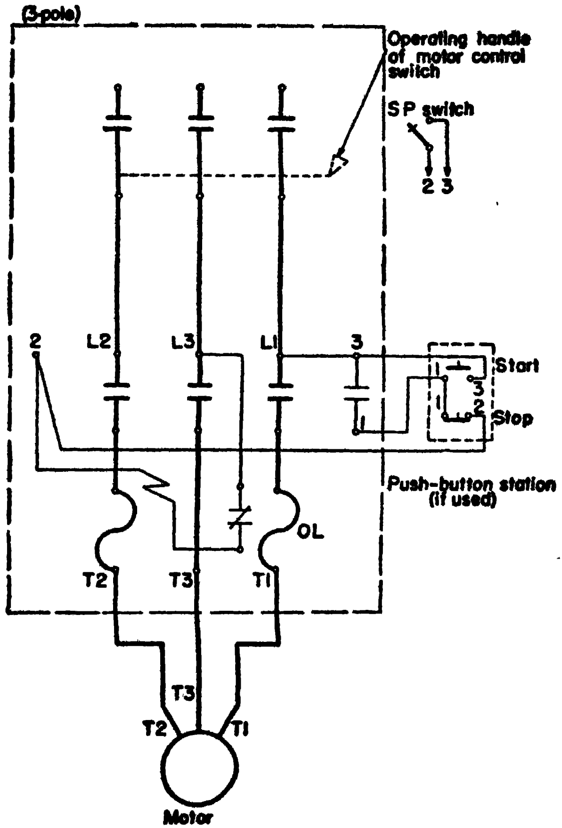


FIG. 6,889.—Wiring diagram for *a.c.* magnetic motor starter shown in fig. 6,888. This starter in addition to the two-element temperature overload relay incorporates facilities for remote control operation by means of a push button station when desired. *Operation:* Assuming the *start-stop* push button be used with the starter, pushing the *start* button closes the starting contactor, and thus connects the motor to the line. The motor is disconnected from the line by pushing the *stop* button. The action of the contactor is controlled by means of an operating coil incorporated in the motor starter. Directly across-the-line starters of this type are usually limited in sizes to about 25 *h.p.* in the lower voltage ranges (110 to 220 volts) because of undesirable line-voltage fluctuations encountered.—*Courtesy General Electric Co.*

In any circuit the loss in percentage, or

$$\%\ \text{loss} = \frac{\text{drop}}{\text{impressed pressure}} \times 100$$

from which

$$\text{drop} = \frac{\%\ \text{loss} \times \text{impressed pressure}}{100} \qquad (2)$$

Substituting equation (2) in equation (1)

$$\text{circular mils} = \frac{\dfrac{\text{amperes} \times \text{feet} \times 21.6}{\%\ \text{loss} \times \text{imp. pressure}}}{100}$$

$$= \frac{\text{amperes} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{imp. pressure}} \qquad (3)$$

Equation (3) is modified for calculation in terms of watts as follows: The power in watts is equal to the *applied voltage* multiplied by the current, that is to say, the power is equal to the *volts at the consumer's end of the circuit* multiplied by the current, or simply

$$\text{watts} = \text{volts} \times \text{amperes}$$

from which

$$\text{amperes} = \frac{\text{watts}}{\text{volts}} \qquad (4)$$

$$\text{circular mils} = \frac{\dfrac{\text{watts}}{\text{volts}} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{volts}}$$

$$= \frac{\text{watts} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{volts}^2} \qquad (5)$$

This formula (5) applies to a direct current two wire circuit, and to adapt it to any alternating current circuit it is only necessary to use the letter M instead of the number 2,160. thus

$$\text{circular mils} \quad \frac{\text{watts} \times \text{feet} \times M}{\%\,\text{loss} \times \text{volts}^2} \qquad (6)$$

in which M is a coefficient which has various values according to the kind of circuit and value of the power factor. These values are given in the following table:

VALUES OF M

SYSTEM	POWER FACTOR									
	1.00	.98	.95	.90	.85	.80	.75	.70	.65	.60
Single phase	2,160	2,249	2,400	2,660	3,000	3,380	3,840	4,400	5,112	6,000
Two phase (4 wire)	1,080	1,125	1,200	1,330	1,500	1,690	1,920	2,200	2,556	3,000
Three phase (3 wire)	1,080	1,125	1,200	1,330	1,500	1,690	1,920	2,200	2,556	3,000

It must be evident that when 2,160 is taken as the value of M, formula (6) applies to a two wire direct current circuit and also to a single phase *a.c.* circuit when the power factor is unity.

In the table, the value of M, for any particular power factor is found by dividing 2,160 by the square of that power factor for single phase and twice the square of the power factor for two phase and three phase.

NOTE.—The above table is calculated as follows: For *single phase* M = 2,160 ÷ power factor^2 × 100; for *two phase* four wire, or three phase three wire, M = ½ (2,160 ÷ power factor^2) 100. Thus the value of M for a single phase line with power factor .95 = 2,160 ÷ .95^2 × 100 = 2,400.

For ordinary calculations however, it is customary to use tables which take into account such factors as wire spacing, power factor, frequency, etc. Accordingly in order to determine the voltage drop of an alternating current circuit, the following formula may be used:

$$\text{Voltage drop} = \frac{\%\ \text{Loss} \times E}{100} \times S \qquad (7)$$

VALUE OF "S" FOR 60 CYCLES

Size of wire B. & S. gauge	Area in circular mils.	.98 power factor					.90 power factor					.80 power factor					.70 power factor				
		Spacing of conductors					Spacing of conductors					Spacing of conductors					Spacing of conductors				
		1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″
500,000	500,000	1.21	1.45	1.61	1.77	1.92	1.32	1.80	2.11	2.44	2.75	1.27	1.89	2.25	2.64	3.03	1.14	1.73	2.1[illegible]	[illegible]	[illegible]
300,000	300,000	1.15	1.29	1.38	1.48	1.57	1.19	1.47	1.66	1.84	2.02	1.11	1.46	1.68	1.90	2.12	1.00	1.23	1.5[illegible]	1.78	2.01
0,000	211,600	1.12	1.22	1.28	1.34	1.41	1.13	1.33	1.45	1.58	1.63	1.03	1.27	1.43	1.58	1.75	1.00	1.14	1.39	1.45	[illegible]
000	167,800	1.09	1.18	1.22	1.28	1.29	1.08	1.23	1.33	1.44	1.53	1.00	1.16	1.28	1.41	.153	1.00	1.02	1.15	[illegible]	[illegible]
00	133,100	1.07	1.14	1.18	1.21	1.25	1.03	1.16	1.24	1.32	1.40	1.00	1.07	1.17	1.27	1.36	1.00	1.00	[illegible]	1.1[illegible]	1.21
0	105,500	1.05	1.10	1.14	1.17	1.20	1.00	1.09	1.16	1.22	1.28	1.00	1.00	1.07	1.15	1.22	1.00	1.00	1.00	1.06	[illegible]
1	83,690	1.04	1.08	1.10	1.13	1.15	1.00	1.05	1.09	1.14	1.19	1.00	1.00	1.00	1.05	1.11	1.00	1.00	[illegible]	[illegible]	[illegible]
2	66,370	1.02	1.06	1.08	1.10	1.12	1.00	1.00	1.04	1.08	1.12	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.00	[illegible]
3	52,630	1.02	1.04	1.06	1.07	1.09	1.00	1.00	1.00	1.03	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	[illegible]	1.00
4 5	41,740 33,100	1.00	1.02	1.03	1.04	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6 7	26,250 20,820	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8 9 10	16,510 13,090 10,380	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Where the % loss is a percentage of the applied power, that is, the power delivered to the motor or apparatus and not a percentage of the power at the *a.c.* generator; E, is the voltage at the consumers end of the circuit. The coefficient S, has various

values as given in the accompanying table. These values are substantially true for transmission lines having a length of up to 20 miles and for voltages up to 25,000. On longer lines, due to the capacity effect the voltage drop will be somewhat inaccurate.

Current Calculation.—As previously stated, the effect of power factor less than unity, is an increase in current, and consequently a conductor of somewhat larger capacity is required for a lower power factor.

For single phase alternating current, the current flowing at the motor terminal, is:

$$I = \frac{\text{HP} \times 746}{E \times \text{Power factor} \times \text{Efficiency}} \tag{8}$$

Similarly for a two phase motor

$$I = \frac{\text{HP} \times 746}{2\,E \times \text{Power factor} \times \text{Efficiency}} \tag{9}$$

and for a three phase motor, the current

$$I = \frac{\text{HP} \times 746}{1.73 \times E \times \text{Power factor} \times \text{Efficiency}} \tag{10}$$

Motor Horsepower.—Motor horsepowers may conveniently be calculated from instrument readings when desired. The formulas are as follows:

D.C. Motors.

$$\text{HP} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency}}{746} \tag{11}$$

Single phase A.C. Motors

$$\text{HP} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor}}{746} \tag{12}$$

Two phase A.C. Motors

$$HP = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor} \times 2}{746} \quad (13)$$

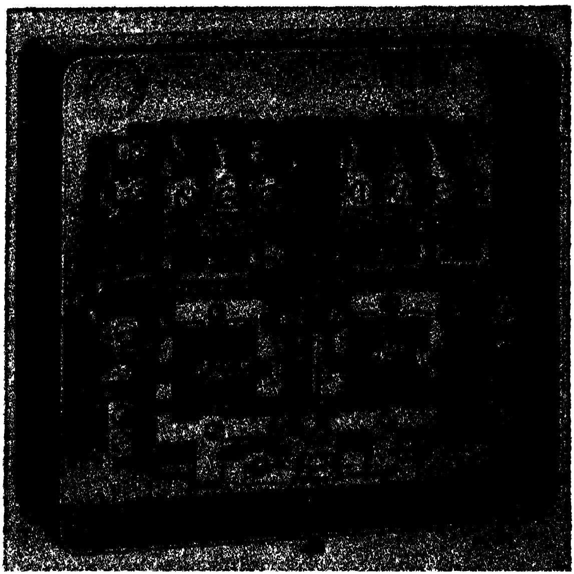


FIG. 6,890.—Illustrating typical *a.c.* magnetic reversing motor starter with front cover removed. This starter consists essentially of two magnetic contactors (one of which is being used for operating the motor in the reverse direction), one temperature overload relay, and a three-button push button station, or their equivalent to control the starter.—*Courtesy General Electric Co.*

Three phase A.C. Motors

$$HP = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor} \times 1.73}{746} \quad (14)$$

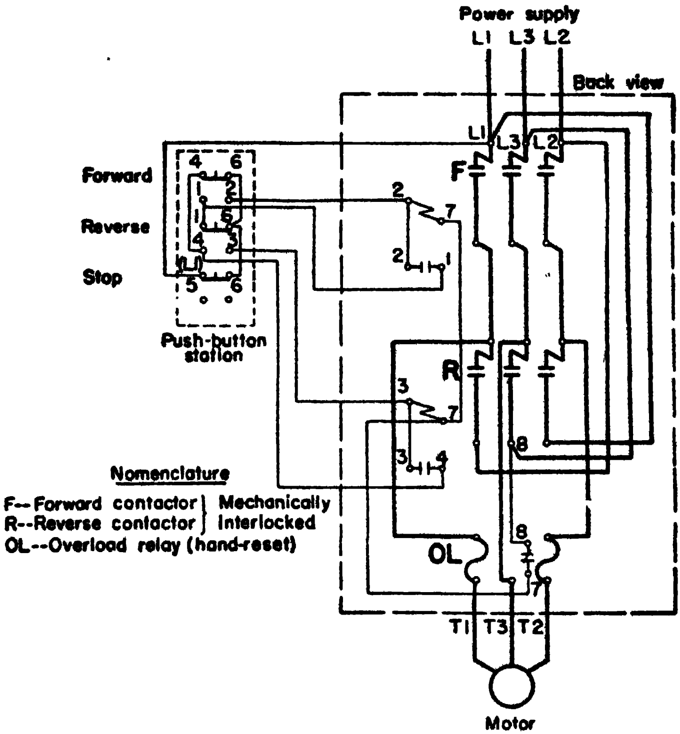


FIG. 6,891.—Wiring diagram for *a.c.* magnetic reversing motor starter shown in fig. 6,890. ***Operation:*** When the *forward* button is depressed contactor F closes and applies power to the motor. A holding circuit for the coil of F is established around the foreward push button by auxiliary interlock F. The motor continues to run until shut down by depressing the *stop* button, by tripping of the overload relay, or by power failure. Following an overload condition which causes relay OL, to trip, it is necessary to reset the relay contact by hand before the motor can be restarted. Operation of the motor in the reverse direction is obtained by the *reverse* button. The back, or normally closed contacts of the directional push-button units are used for electric interlocking and prevent the coils of contactors F and R being energized at the same time. With this arrangement it is also possible to reverse the motor direct from the *forward* and *reverse* button, without first operating the stop button.—*Courtesy General Electric Co.*

Example.—*What size wire must be used on a single phase circuit 2,000 ft. in length to supply 3 kw. at 220 volts with a loss of 4%, the power factor being 90%?*

Solution.—Inserting values in formula (6) we obtain:

$$\text{Circular mils} = \frac{3{,}000 \times 2{,}000 \times 2{,}660}{4 \times 220^2} = 82{,}438$$

With reference to wire table (page 3,073) the nearest larger wire size is No. 1 A.W.G. which has an area of 83,690 cir. mils, and this should be used.

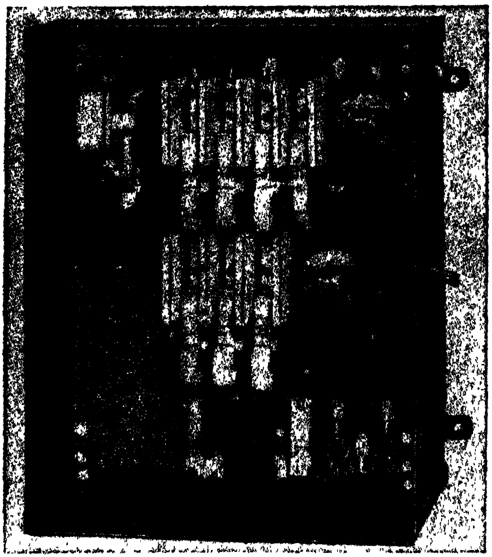


FIG. 6,892.—Typical automatic primary resistor motor starter with front cover removed.—*Courtesy General Electric Co.*

Example.—*A* 50 *h.p.* 60 *cycle single phase* 440 *volt induction motor, having a full load efficiency of* 92% *and a power factor of* 80% *is to be operated at a distance of* 1,000 *feet from the alternator. The wires are to be spaced* 6 *in. apart and the voltage drop is* 5%.

Calculate.—(*a*) Electrical horsepower; (*b*) Watts; (*c*) Apparent load; (*d*) Line current; (*e*) Size of wires; (*f*) Voltage drop; (*g*) Voltage at the alternator.

Solution.—

(*a*) $\text{Electrical horsepower} = \frac{\text{Brake horsepower}}{\text{Efficiency}} = \frac{50}{0.92} = 54.3$ **Ans.**

(b) $$\text{Watts} = 54.3 \times 746 = 40{,}508 \quad \textit{Ans.}$$

(c) Apparent load $$= \frac{\text{Watts}}{\text{Power factor}} = \frac{40{,}508}{0.8} = 50{,}635 \quad \textit{Ans.}$$

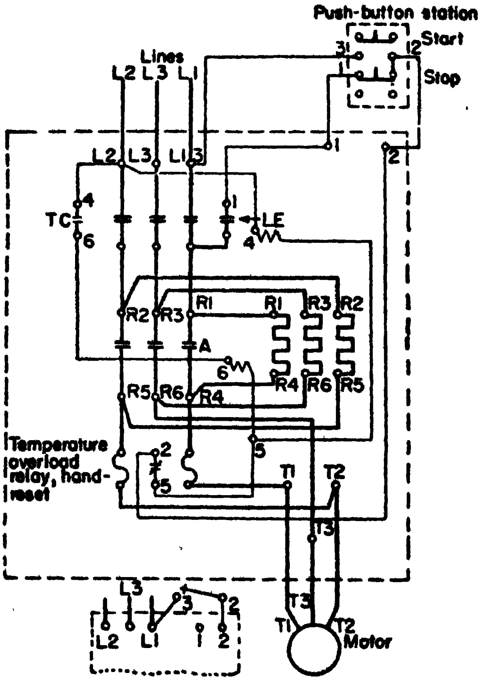


FIG. 6,893.—Wiring diagram of automatic primary resistor motor starter shown in fig. 6,892. A motor starter of this type applies approximately 80% of line voltage to the motor for starting, thus limiting the inrush current to approximately 80% of the full-voltage locked-rotor value and producing a starting torque of approximately 64% of the full voltage locked-rotor value. *Operation:* When the start button is depressed the line contactor closes its contacts connecting the motor to the line through the series line resistors R, at reduced voltage. The transfer from reduced voltage to full voltage is made by means of definite time interlock TC mechanically actuated by the closing of the line contactor. After a predetermined time contacts TC operates which in turn energizes the coil of the accelerating contactor which in closing short-circuits the series line resistors without interrupting the circuit.—*Courtesy General Electric Co*

(*d*) Line current $= \frac{\text{Apparent load}}{\text{Volts}} = \frac{50{,}635}{440} = 115$ *Ans.*

(*e*) Size of wires. Cir. Mils =

$$\frac{\text{Watts} \times \text{Feet} \times \text{M}}{\%\ \text{Loss} \times \text{Volts}^2} = \frac{40.508 \times 1{,}000 \times 3{,}380}{5 \times 440 \times 440} = 141{,}443 \ \textit{Ans.}$$

From table (page 3,073) nearest size larger wire is 3/0 A.W.G. which should be used.

(*f*) Voltage drop $= \frac{\%\ \text{Loss} \times E}{100} \times S = \frac{5 \times 440 \times 1.28}{100} = 28.16$ *Ans.*

(*g*) Voltage at alternator = volts at motor + drop = 440 + 28.16 = 468.16 *Ans.*

Example.—*A circuit supplying current at 440 volts, 60 cycles, with 5% voltage loss and a power factor of 80% is composed of No. 2 wires spaced one foot apart. What is the drop in the line?*

Solution.—Substituting the given values in formula (7) and the value of S, as obtained from the table, we obtain:

$$\text{Voltage drop} = \frac{5 \times 440 \times 1}{100} = 22 \text{ volts. } \textit{Ans.}$$

Example.—*A single phase 50 horsepower 440 volt motor has a full load efficiency of 90% and a power factor of 80%. How much current will the motor draw from the line?*

Solution.—Applying formula (8) a substitution of values gives:

$$I = \frac{50 \times 746}{440 \times 0.9 \times 0.8} = 117.7 \ \textit{amp. Ans.}$$

Example.—*A 10 kw. 220 volt single phase motor and light load has a combined power factor and efficiency of 85 and 80% respectively. What is the current?*

Solution.—With reference to formula (8) page 3,033 we have:

$$I = \frac{10{,}000}{220 \times 0.85 \times 0.8} = 67 \ \textit{amp.} \text{ (nearly) } \textit{Ans.}$$

Example.—*A 25 h.p. three phase induction motor has a full load efficiency of 85% and a power factor of 80%. How much current will the motor draw from the 220 volt line?*

Solution.—By substituting our values in formula (10) we obtain:

$$I = \frac{25 \times 746}{1.73 \times 220 \times 0.8 \times 0.85} = 72 \ \textit{amp.} \text{ (approximately) } \textit{Ans.}$$

***Example.**—A 440 volt, three phase induction motor draws 40 amp. from the line. Calculate the motor output in horsepower when the efficiency of the motor and power factor are 85 and 80% respectively.*

Solution.—A substitution of values in formula (14) gives:

$$\text{Horsepower} = \frac{440 \times 40 \times 0.85 \times 0.80 \times 1.73}{746} = 27.8 \quad \textit{Ans.}$$

***Example.**—An industrial load of 450 kilowatts is operated at a power factor of 65%. What will be the rating of a synchronous condenser (over-excited synchronous motor without load) to raise the power factor to 90%?*

Solution.—Since the voltage is constant, the kilowatts and quadrature kilovolt-amperes are proportional to the energy quadrature currents respectively. In our particular problem the apparent power component is:

$$\textit{Kva.} = \frac{450}{0.65} = 692$$

The reactive power component is:

$$\sqrt{692^2 - 450^2} = 525 \textit{ kva.}$$

With the power factor raised to 90% the reactive power will be:

$$\frac{450}{0.9} = 500 \textit{ kva.}$$

which will have a wattless or apparent power component of

$$\sqrt{500^2 - 450^2} = 218 \textit{ kva.}$$

It is obvious that the synchronous condenser must supply the difference between 525 and 218 *kva*. or 307 *kva*. A 300 *kva*. synchronous condenser would therefore meet the foregoing requirements. *Ans.*

***Example.**—A direct current motor takes 720.8 amperes at 115 volts and has an efficiency of 90%. How many horsepower does it deliver?*

Solution.—

$$\text{Input to motor} = 720.8 \times 115 = 82{,}892 \text{ watts}$$

$$\text{Output of motor} = 82{,}892 \times 0.9 = 74{,}603 \text{ watts}$$

Horsepower (at motor pulley)

$$= \frac{74{,}603}{746} = 100 \textit{ h.p.} \text{ (approximately).} \quad \textit{Ans.}$$

TEST QUESTIONS

1. *Name two wiring systems used in direct current distribution.*
2. *How does a three wire D.C. generator differ from that of a two wire generator?*
3. *What is the function of a balance coil and how is it connected to the mains?*
4. *How is a balancer set connected to obtain a three wire D.C. distribution system?*
5. *What is the disadvantage in employing a series lamp system of distribution?*
6. *Draw a diagram showing lamp connections to a two and three wire D.C. distributor panel.*
7. *Why is an equalizer connection required for parallel operation of D.C. generators?*
8. *What is meant by a load center and how may it be calculated?*
9. *Define Kelvin's law.*
10. *What is the meaning of* 10.8 *as used in wire calculations?*
11. *Define circular mils.*
12. *What is the mathematical relations between resistance, current and voltage in a D.C. circuit?*
13. *What is the Ohmic resistance of one circular mil-foot of copper wire?*
14. *What is the effect of resistance on current?*

CHAPTER 98

Power Wiring

Wiring of Motors (Code Provisions).—All motor wiring should be performed according to the requirements of the *National Electrical Code* in addition to existing *local Codes* and requirements in force at the place of installation

Since the detailed requirements of the Code with respect to motor circuits are too numerous to be fully enumerated only the basic general rules for motors are abstracted here.

Fig. 7,360 represents a schematic diagram of a motor circuit together with feeder and branch circuit equipment all lettered for proper identification.

(*Note A*) ***Feeder Overcurrent Protection.***—A feeder which supplies motors shall be provided with overcurrent protection which shall not be greater than the largest rating or setting of the branch circuit protective device for any motor of the group (based on tables 26 and 27, pages 3,080 and 3,081) plus the sum of the full load currents of the other motors of the group.

(*Note B*) ***Feeder Conductors.***—Conductors supplying two or more motors shall have a current carrying capacity of not less than 125% of the full load current rating of the highest rated motor in the group, plus the sum of the full-load currents of the remaining motors supplied by the feeder.

(*Note C*) ***Motor Branch Circuit Conductors.***—Branch circuit conductors supplying an individual motor shall have a current carrying capacity of not less than 125% of the motor full load current rating. If the circuit supplies two or more motors, computation of the conductor size should be made in the same manner as that given for feeder conductors.

(*Note D*) ***Motor Branch Circuit Overcurrent Protection.***—The motor branch circuit overcurrent device shall be capable of carrying the starting current of the motor. The Code specifies the maximum permissible size as a percentage of the full load circuit of the motor, depending upon its type, starting method and locked rotor current. These maximum values are given in table 20, pages 3,074 to 3,077.

Note E) Disconnecting Means.—The disconnecting means for each motor and controller shall consist of an indicating type disconnecting switch or circuit breaker, having a current carrying capacity of not less than 115% of the motor name plate current rating, and arranged so as to disconnect the ungrounded conductors.

For motors less than 50 *h.p.* the switch is generally rated in horsepower whereas motors rated at more than 50 *h.p.* have their disconnecting means rated also in amperes.

The disconnecting means serving a group of motors may be a single disconnecting switch when driving a single machine or piece of apparatus, or protected by one set of overcurrent devices, or in a single room within sight of the disconnecting means.

(Note F) Motor Running Overcurrent Device.—Continuous duty motors rated at more than one horsepower shall have a running overcurrent protection not greater than 125% of the full load rating of the motor. The motor running overcurrent device may be shunted out during starting period of the motor, provided the device by which the overcurrent protection is shunted out or cut out cannot be left in the starting position, and the motor shall be considered as protected during the starting period if fuses or time delay circuit breakers rated or set at not over 400% of the full load current of the motor, are so located in the circuit as to be operative during the starting period of the motor.

(Note G) Motor Controller.—A controller shall be provided for each motor or group of motors as in paragraph (E) above.

Each controller shall normally be in sight of the motor and shall be capable of starting and stopping the motor which it controls, and for an alternating current motor shall be capable of interrupting the stalled rotor current of the motor. Controllers generally are rated in horsepower.

(Note H) Secondary Circuit Conductors.—Conductors connecting the secondary of a wound rotor alternating current motor to its controller shall have a current carrying capacity which is not less than 125% of the full load secondary current of the motor if for continuous duty. The capacity of the conductors between controller and resistor shall not be less than 110% of full load secondary current for continuous duty motors.

Motor Circuits

The following general groupings or types of circuit layouts should be followed in wiring of motors, in order that the installation will conform with the requirements of the *Code*.

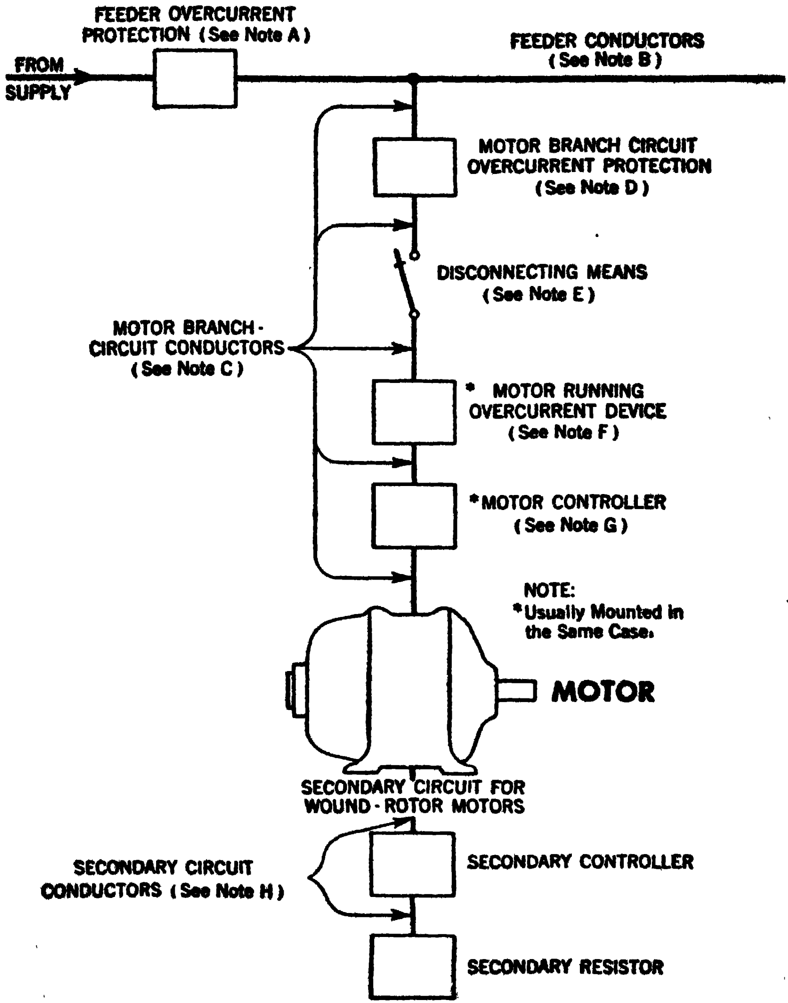


FIG. 7,360.—Schematic diagram showing typical motor feeder and branch circuits. For notes see text.

In general there are five different types of motor wiring as follows:

Type 1.—A separate branch circuit to each motor from a power panel-board or distribution center as illustrated in fig. 7,361.

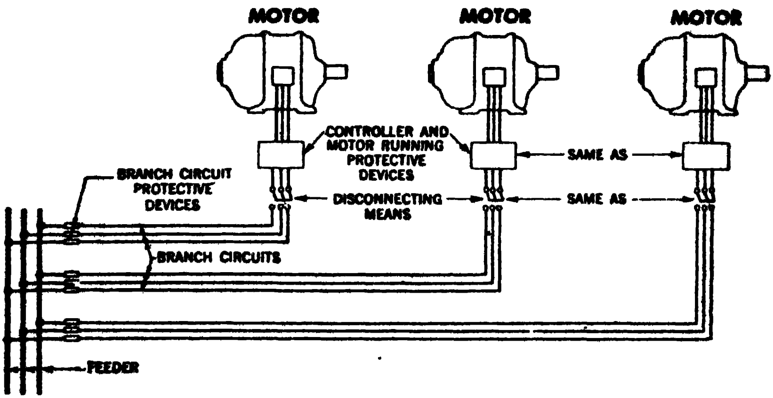


FIG. 7,361.—Showing general layout for *type 1* wiring. A wiring layout of this type is very common and may be used for almost any condition.

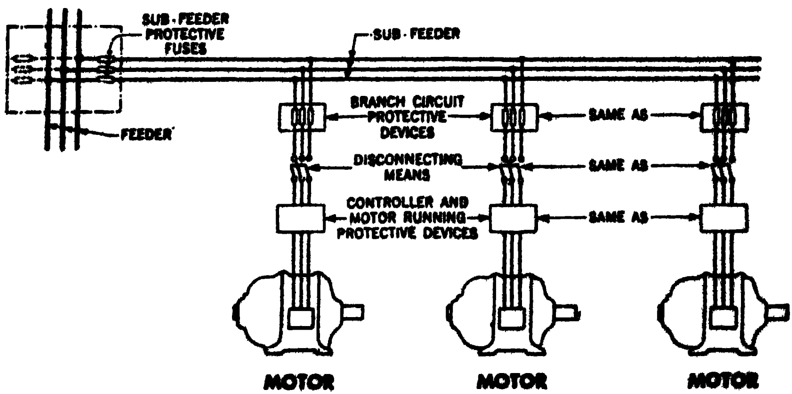


FIG. 7,362.—General layout for *type 2* wiring. A wiring layout of this type is used chiefly in industrial plants where a large number of motors are used to drive individual machines.

Type 2.—A feeder or subfeeder may supply all motors with branch circuits tapped to the subfeeder at convenient points as illustrated in fig. 7,362. This wiring method is similar to that shown in fig. 7,361, except that the branch circuit overcurrent protective devices are mounted individually at the points where taps are made to the subfeeder instead of at the branch circuit distribution center.

Type 3.—A feeder or subfeeder may supply all motors with branch circuits tapped to the subfeeder at convenient points as illustrated in fig. 7,363. This wiring method is similar to that shown in fig. 7,362, except

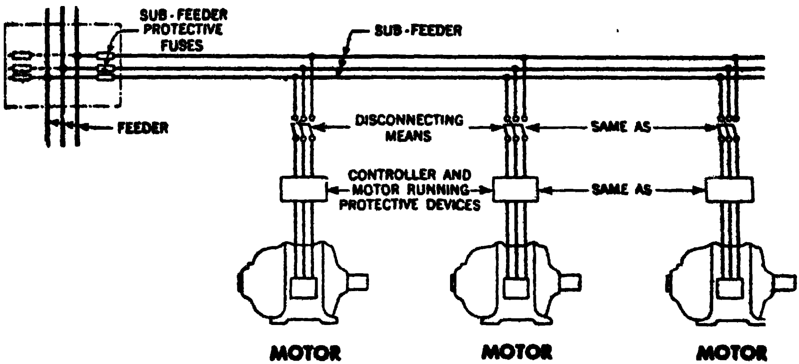


FIG. 7,363.—Showing layout for *type 3* wiring.

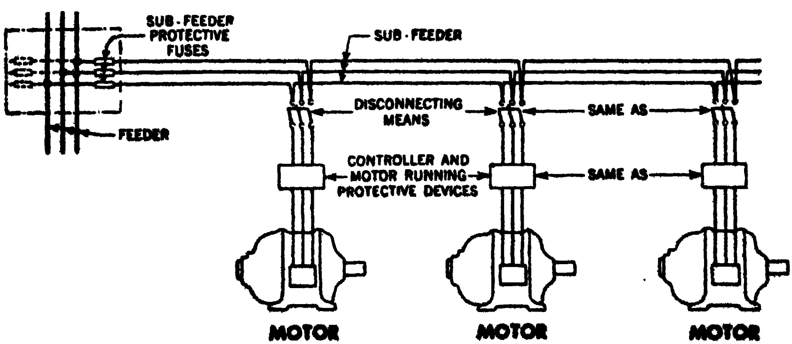


FIG. 7,364.—Layout for *type 4* wiring. This wiring method differs from that shown in fig. 7,363, mainly in that a subfeeder is connected directly to the disconnecting means to each motor. A wiring scheme of this type will show a saving in cost over either of the foregoing wiring layouts, if the subfeeder can be brought directly to each controller.

that no overcurrent devices are provided to protect the subfeeder taps. In this case the motor branch circuits are considered as originating at the controller.

Type 4.—A feeder or subfeeder may be carried directly to the disconnecting means or controller for each motor as illustrated in fig. 7,364. In all other respects this wiring method is similar to that shown in fig. 7,363.

Type 5.—A group of small motors each having a full load rated current not exceeding 6-*amp*. each may be used on a motor branch circuit protected at not more than 15-*amp*. at 125 volts or 10-*amp*. at 250 volts, or with lamps and other appliances on the 15, 20 and 25-*amp*. branch circuits, as illustrated in figs. 7,365 and 7,366. Motors connected in these circuits are required to be provided with running overcurrent protective devices in special cases.

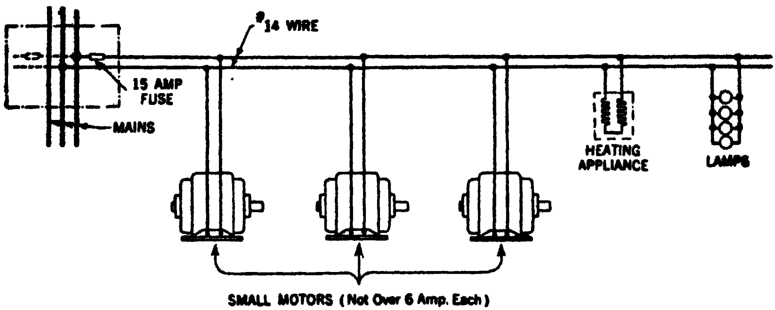


Fig. 7,365.—Layout for *type 5* wiring. In this wiring scheme a 15-*amp*. branch circuit is supplying small motors and other loads.

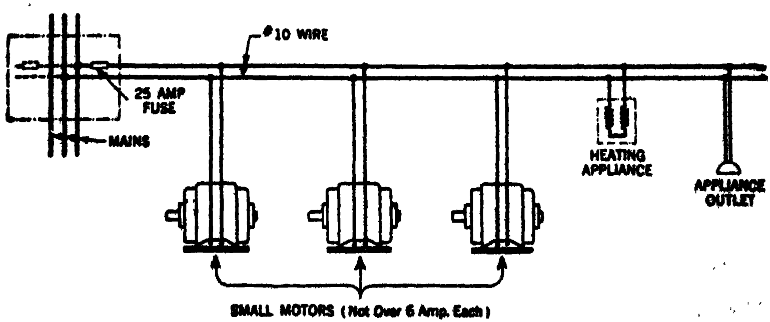


Fig. 7,366.—Layout for *type 5* wiring. Here a 25-*amp*. branch circuit supplies small motors and other loads.

Branch Circuits.—By definition a branch circuit is that portion of the wiring system extending beyond the final overcurrent device protecting the circuit. The essential parts of a typical motor branch circuit as previously described consists of: (a) *the branch circuit conductors*; (b) *the branch circuit overcurrent devices*, and (c) *the motor running protective devices*. These parts of a motor circuit are shown in fig. 7,367.

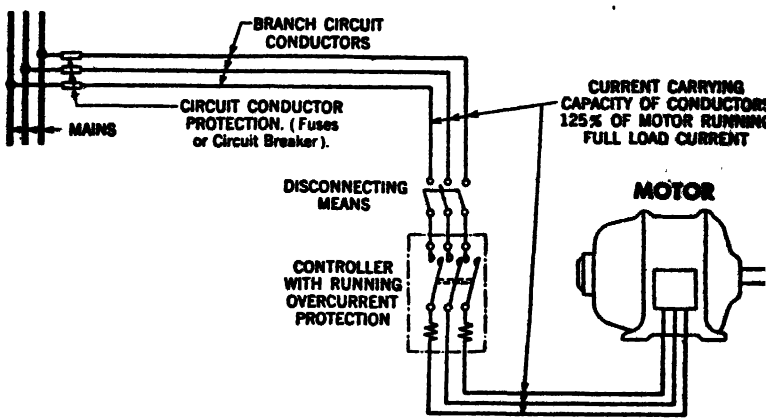


FIG. 7,367.—Showing essential component parts of typical branch circuit motor wiring.

Size of Conductors for Motor Circuits

Branch circuit conductors supplying an individual motor shall have a current carrying capacity of not less than 125 percent of the motor full load current rating; provided that conductors for motors used for short time, intermittent, periodic or varying duty, may have a current capacity of not less than the percentage of the motor name plate current rating as shown in the following table, unless the authority enforcing the *Code* grants special permission for conductors of smaller size.

As noted in the table, the necessary carrying capacity of conductors depend upon the class of service and upon the rating of the motor. A motor having a 15-minute rating for example, is designed to deliver its rated horsepower during periods of approximately 15 minutes each, with cooling intervals between the operating period. For long runs, it may be necessary in order to avoid excessive voltage drop, to use conductors of larger sizes than that found by reference to tables.

Classification of Service	Percentages of Name Plate Current Rating			
	5 Minute Rating	15 Minute Rating	30 & 60 Minute Rating	Continuous Rating
Short-Time Duty				
Operating valves, raising or lowering rolls	110	120	150	...
Intermittent Duty				
Freight and passenger elevators, shop cranes, tool heads, pumps, drawbridges, turntables, etc.	85	85	90	140
Periodic Duty				
Hoists, rolls, ore and coal-handling machines	85	90	95	140
Varying Duty	110	120	150	200
	or lower at the discretion of the authorities enforcing the regulations.			

Wound Rotor Motors.—Conductors connecting the secondary of a wound rotor *a.c.* motor to its controller shall have a current carrying capacity, which is not less than 125 per cent of the full load secondary current of the motor if for continuous duty. For other than continuous duty, these conductors shall have a carrying capacity in per cent of full load secondary current not less than that specified in the foregoing table.

Where the secondary resistor is separate from the controller, the carrying capacity of the conductors between controller and resistor shall be not less than that given in the following table.

Resistor Duty Classification	Carrying capacity of wire in per cent of full load secondary current
Light starting duty	35
Heavy starting duty	45
Extra heavy starting duty	55
Light intermittent duty	65
Medium intermittent duty	75
Heavy intermittent duty	85
Continuous duty	110

The full load secondary current of wound rotor type motors shall be obtained from the manufacturers name plate.

Starters or combined starters and speed regulating devices as used in the secondary circuits of wound rotor induction motors usually consist of a dial type or drum controller with accompanying resistor units which in the case of the dial type controller is a part of the controller itself, whereas drum controllers have separately mounted resistors which are connected to the controller proper according to the manufacturers diagram.

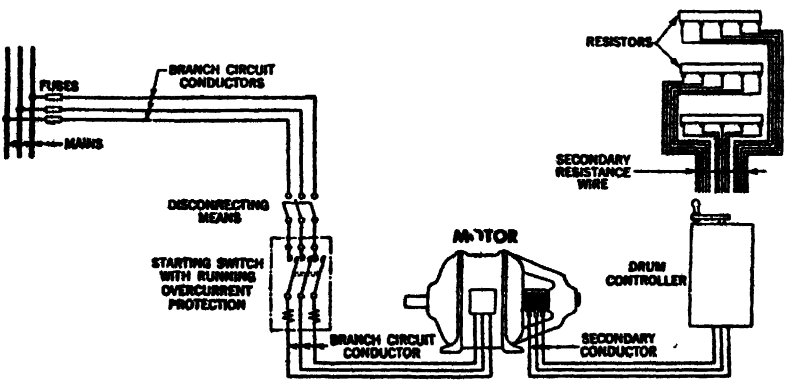


FIG. 7,368.—Wiring diagram of typical wound rotor motor with drum controller. Speed regulation drum controllers may be of either the motor reversing or non-reversing type. Secondary resistors for wound rotor motors are as a rule designed for star connection.

Conductors Supplying Two or More Motors.—Conductors supplying two or more motors shall have a current carrying capacity of not less than 125% of the full load current rating of the highest rated motor in the group, plus the sum of the full load current ratings of the remainder of the motors in the group. (See example, page 3,067.)

Motor Overcurrent Protection

The following provisions specify overcurrent devices intended to protect the motors, the motor control apparatus and the branch circuit conductors against excessive heating due to motor overloads. *Continuous duty motors* shall be protected against overload as follows:

Motors of More than One Horsepower.—For a motor rated more than one horsepower, this protection shall be secured by the use of one of the following means:

1. A separate overcurrent device which is responsive to motor current. This device shall be rated or set at not more than 125% of the motor full load current rating for an open type motor marked to have a temperature rise not over 40C, and at not more than 115% for all other types of motors.

2. A protective device integral with the motor which is responsive to motor current or to both motor current and temperature. This device must be approved for use with the motor which it protects on the basis that it will interrupt current to the motor when the motor is operated in an ambient temperature of 40C and with overcurrent of the percentage values given in paragraph 1. If the motor current interrupting device is separate from the motor and its control circuit is operated by a protective device integral with the motor, it must be so arranged that the opening of the control circuit will result in interruption of current to the motor.

Motors of Less than One Horsepower.—Motors of one horsepower or less which are manually started, and which are within sight from the starter location, shall be considered as protected against overcurrent by the overcurrent device protecting the conductors of the branch circuit. This branch circuit overcurrent device shall not be larger than that specified in table 20, page 3,074 except that any such motor may be used at 125 volts or less on a branch circuit protected at 20 *amp*. Any such motor which is out of sight* from the starter location shall be protected as specified in the following paragraphs for automatically started motors.

Any motor of *one horsepower or less* which is started *automatically* shall be protected against overcurrent by use of one of the following means:

1. A separate overcurrent device which is responsive to motor current. This device shall be rated or set at not more than 125% of the motor full load current rating for an open type motor marked to have a temperature rise not over 40C, and at not more than 115% for all other types of motors.

*NOTE.—A distance of more than 50 feet is considered equivalent to being out of sight.

2. A protective device integral with the motor which is responsive to motor current or to both motor current and temperature. This device must be approved for use with the motor which it protects on the basis that it will prevent dangerous overheating of the motor due to overload or failure to start. If the motor current interrupting device is separate from the motor and its control circuit is operated by a protective device integral with the motor, it must be so arranged that the opening of the control circuit will result in interruption of current to the motor.

3. If part of an approved assembly which does not normally subject the motor to overloads and which is also equipped with other safety controls (such as the safety combustion controls of a domestic oil burner) which protect the motor against damage due to stalled rotor current. Where such protective equipment is used it shall be indicated on the name plate of the assembly where it will be visible after installation.

4. If the impedance of the motor windings is sufficient to prevent overheating due to failure to start, the motor may be protected as previously stated, for motors of less than one horsepower manually started.

Many alternating current motors of less than 1/20-*h.p.*, such as clock motors, series motors, etc. and also some larger motors such as torque motors, come within this classification. It does not include split phase motors having automatic switches to disconnect the starting windings.

The secondary circuits of wound rotor (slip ring) alternating current motors, including conductors, controllers, resistors, etc., shall be considered as protected against overcurrent by the motor running overcurrent device.

Intermittent and Similar Duty Motors.—A motor used for a condition of service which is inherently short time, intermittent, periodic or varying duty is considered as protected against overcurrent by the branch circuit overcurrent device, provided the overcurrent protection does not exceed that specified in tables 26 and 27 pages 3,080 and 3,081.

Any motor is considered to be for continuous duty unless the nature of the apparatus which it drives is such that the motor cannot operate continuously with load under any conditions of use.

Size of Protective Devices.—Where the values specified for motor running overcurrent protection do not correspond to the standard sizes or ratings of fuses, non-adjustable circuit breakers,

thermal cutouts, thermal relays, the heating elements of thermal trip motor switches, or possible settings of adjustable circuit breakers adequate to carry the load, the next higher size, rating or setting may be used, but not exceeding 140 per cent of the motor full load current rating. If not shunted during the starting period of the motor, the protective device shall have sufficient time delay to permit the motor to start and accelerate its load.

Shunting During Starting Period.—If the motor is manually started, the running overcurrent protection may be shunted or cut out of circuit during the starting period of the motor (as shown in fig. 7,369), provided the device by which the overcurrent protection is shunted or cut out cannot be left in the starting position, and the motor shall be considered as protected against overcurrent during the starting period if fuses or time delay circuit breakers rated or set at not over 400 per cent of the full load current of the motor, are so located in the circuit as to be operative during the starting period of the motor. The motor running overcurrent protection shall not be shunted or cut out during the starting period if the motor is automatically started.

Fuses.—If fuses are used for motor running protection a fuse shall be inserted in each ungrounded conductor.

Devices Other Than Fuses.—If devices other than fuses are used for motor running protection, the following table shall govern the minimum allowable number and location of overcurrent units such as trip coils, relays or thermal cutouts.

Kind of Motor	Supply System	Number and location of overcurrent units, such as trip coils, relays or thermal cut-outs
1-phase *a.c.* or *d.c.*	2-wire, 1-phase *a.c.* or *d.c.*, ungrounded	1 in either conductor
1-phase *a.c.* or *d.c.*	2-wire, 1-phase *a.c.* or *d.c.*, one conductor grounded	1 in ungrounded conductor
1-phase *a.c.* or *d.c.*	3-wire, 1-phase *a.c.* or *d.c.*, grounded-neutral	1 in either ungrounded conductor
2-phase *a.c.*	3-wire, 2-phase *a.c.*, ungrounded	2, one in each phase
2-phase *a.c.*	3-wire, 2-phase *a.c.*, one conductor grounded	2 in ungrounded conductors
2-phase *a.c.*	4-wire, 2-phase *a.c.*, grounded or ungrounded	2, one per phase in ungrounded conductors
2-phase *a.c.*	5-wire, 2-phase *a.c.*, grounded neutral or ungrounded	2, one per phase in any ungrounded phase wire
3-phase *a.c.*	3-wire, 3-phase *a.c.*, ungrounded	2 in any 2 conductors
3-phase *a.c.*	3-wire, 3-phase *a.c.*, one conductor grounded	2 in ungrounded conductors
3-phase *a.c.*	3-wire, 3-phase *a.c.*, grounded-neutral	2 in any 2 conductors
3-phase *a.c.*	4-wire, 3-phase *a.c.*, grounded-neutral or ungrounded	2 in any 2 conductors, except the neutral

Number of Conductors Disconnected by Overcurrent Device.—Motor running protective overcurrent devices, other than fuses or thermal cutouts shall simultaneously disconnect a

sufficient number of ungrounded conductors, to interrupt current flow to the motor.

It is recommended that all ungrounded conductors be opened if devices accomplishing this are available.

Motor Controller as Running Protection.—A motor controller may also serve as the running overcurrent device if the number of overcurrent units complies with the table shown on page3,053and if these overcurrent units are operative in both the starting and running position in the case of a direct current motor and in the running position in the case of an alternating current motor.

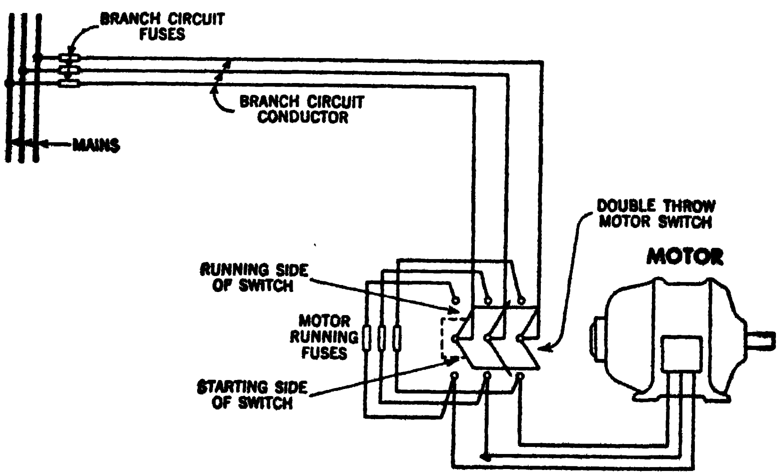


FIG. 7,369.—Wiring diagram showing across the line method of motor starting. The double throw switch is thrown in the lower position at starting, thus shunting out the running fuses. After the motor has attained its normal running speed the switch is thrown in the upper position. The switch must be so constructed that it cannot be left in the starting (or lower) position.

Thermal Cutouts and Relays.—Thermal cutouts, thermal relays and other devices for motor running protection which are

not capable of opening short circuits, shall be protected by fuses or circuit breakers of not over four times the rating of the motor for which they are designed, unless approved for group installation, and marked to indicate the maximum size of fuse by which they must be protected.

Motor running overcurrent devices other than fuses shall have a rating of at least 115 per cent of the full load current rating of the motor.

Automatic Restarting.—A motor running protective device which can restart a motor automatically after overcurrent tripping shall not be installed unless approved for use with the motor which it protects. A motor which can restart automatically after shut-down shall not be installed so that its automatic restarting can result in injury to persons.

Motor Branch Circuit Overcurrent Protection

The following provisions specify overcurrent devices intended to protect the motor branch circuit conductors, the motor control apparatus, and the motors against overcurrent due to short circuits or grounds.

Ratings or Setting for Individual Motors.—The motor branch circuit overcurrent device shall be capable of carrying the starting current of the motor. Overcurrent protection shall be considered as being obtained when this overcurrent device has a rating or setting not exceeding the values given in tables 26 or 27 pages 3,080 and 3,081 provided that where the overcurrent protection specified in the tables are not sufficient for the starting current of the motor, it may be increased but shall in no case exceed 400 per cent of the motor full load current. Fuse ratings calculated on this basis are given in columns 7, 8, 9 and 10, table 20, page 3,074 to 3,077 .

Several Motors on One Branch Circuit.—Two or more motors may be connected to the same branch circuit under the following conditions:

a. Two or more motors each not exceeding 1 horsepower in rating and each having a full load rated current not exceeding 6 amperes, may be used on a branch circuit protected at not more than 20 amperes at 125 volts or less, or 15 amperes at 600 volts or less. Individual running overcurrent protection is unnecessary for such motors unless required by the provisions

b. Two or more motors of any ratings each having individual running overcurrent protection, may be connected to one branch circuit provided all of the following conditions are complied with:

1. Each motor running overcurrent device must be approved for group installation.

2. Each motor controller device must be approved for group installation.

3. The branch circuit must be protected by fuses having a rating equal to that specified for the largest motor connected to the branch circuit plus an amount equal to the sum of the full load current ratings of all other motors connected to the circuit.

4. The branch circuit fuses must not be larger than allowed by specifications covering the thermal cutout or relay protecting the smallest motor of the group.

5. The conductors of any tap supplying a single motor need not have individual branch circuit protection, provided they comply with either of the following: (1) No conductor to the motor shall have a current carrying capacity less than that of the branch circuit conductors, or (2) no conductor to the motor shall have a current carrying capacity less than one third that of the branch circuit conductors, with a minimum in accordance with table the conductors to the motor running protective device being not more than 25 feet long and being protected from mechanical injury.

Combined Overcurrent Protection.—Motor branch circuit overcurrent protection and motor running overcurrent protection may be combined in a single overcurrent device if the rating or setting of the device provides the running overcurrent protection specified

Fuses.—If fuses are used for motor branch circuit overcurrent protection a fuse shall be placed in each ungrounded conductor.

Capacity of Fuseholder.—If fuses are used for motor branch circuit overcurrent protection, the fuseholders shall not be of a smaller size than required to accommodate the fuses specified by table 20, page 3,074 except that where the authority enforcing this code is satisfied that the conditions of maintenance and supervision provide that appropriate fuses for the starting characteristics of the motor will be continually available, fuseholders of smaller size than specified by table 20, may be used.

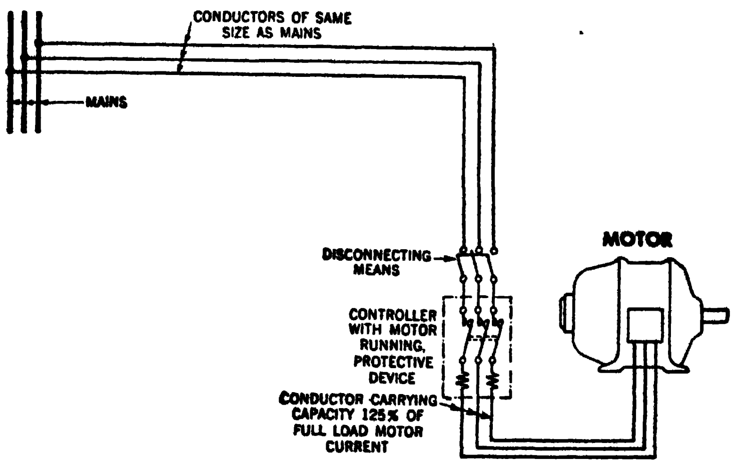


FIG. 7,370.—Motor wiring diagram where the branch circuit conductors are of the same size as the mains. In this case branch circuit protective devices may be omitted.

Rating of Circuit Breaker.—Circuit breakers for motor branch circuit protection shall have a continuous current rating of not less than 115 per cent of the full load current rating of the motors.

Feeder Taps in Inaccessible Location.—If the location of a tap to the feeder conductors is not accessible, the motor branch circuit overcurrent device may be placed where it will be ac-

cessible, provided the conductors between the tap and the overcurrent device have the same overcurrent capacity as the feeder; or provided they have a current carrying capacity of at least ⅓ of the feeder and are not more than 25 feet long and are protected from mechanical injury.

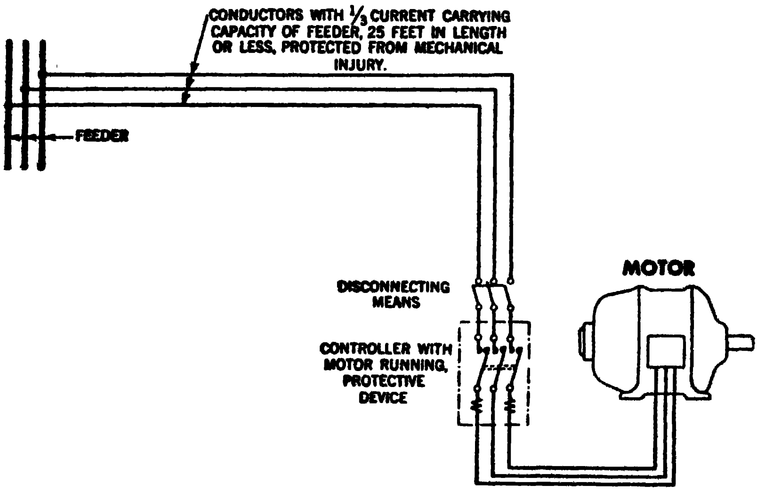


FIG. 7,371.—Wiring diagram of motor circuit where the conductors to motor controller have one-third the current carrying capacity of the feeder. In this case branch circuit protective devices may be omitted.

Selection or Setting of Protective Device.—If the values for branch circuit protective devices given in table 26, page 3,080 or table 27, page 3,081 do not correspond to the standard sizes or ratings of fuses, non-adjustable circuit breakers, or thermal devices, or possible settings of adjustable circuit breakers adequate to carry the load, the next higher size, rating or setting may be used.

A distance of more than 50 feet is considered equivalent to being out of sight.

Motor Feeder Overcurrent Protection

The following provision specify overcurrent devices intended to protect feeder conductors supplying motors against overcurrent due to short circuits or grounds.

Rating or Setting; Motor Load.—A feeder which supplies motors shall be provided with overcurrent protection which shall not be greater than the largest rating or setting of the branch circuit protective device, for any motor of the group, plus the sum of the full load currents of the other motors of the group.

If two or more motors of equal horsepower rating are the largest in the group, one of these motors shall be considered the largest for the foregoing calculations.

If two or more motors of a group must be started simultaneously, it may be necessary to install larger feeder conductors and correspondingly larger ratings or settings of feeder overcurrent protection.

Ratings or Settings; Power and Light Loads.—If a feeder supplies a motor load and in addition a lighting or a lighting and appliance load, the feeder overcurrent protective device may have a rating or setting sufficient to carry the lighting or the lighting and appliance load as determined in accordance with tables 26 and 27, pages 3,080 and 3,081

Motor Controllers*

The following provisions are intended to require suitable controllers for all motors.

*NOTE.—As used in this chapter the term *controller* includes any switch or device which is normally used to start and stop the motor.

Suitability.—Each controller shall be capable of starting and stopping the motor which it controls and for an alternating current motor shall be capable of interrupting the stalled rotor current of the motor.

Rating.—The controller shall have a horsepower rating, which shall not be lower than the horsepower rating of the motor except as follows:

a. For a stationary motor rated at ⅛ horsepower or less that is normally left running and is so constructed that it cannot be damaged by overload or failure to start, such as clock motors and the like, the branch circuit overcurrent device may serve as controller.

b. For a stationary motor rated at 2 horsepower or less, and 300 volts or less, the controller may be a general use switch having an ampere rating at least twice the full load current rating of the motor.

c. For a portable motor rated at ¼ horsepower or less, the controller may be an attachment plug and receptacle.

d. A branch circuit type circuit breaker, rated in amperes only, may be used as a controller. When this circuit breaker is also used for overcurrent protection, it shall conform to the appropriate provision of this chapter governing overcurrent protection.

Opening of Conductors.—Except when the controller serves also as a disconnecting switch, the controller need not open all conductors to the motors.

In grounded conductors one pole of the controller may be placed in a permanently grounded conductor provided the controller is so designed that the pole in the grounded conductor cannot be opened without simultaneously opening all conductors of the circuit.

In Sight of Motor.—A motor and its driven machinery shall be within sight of the point from which the motor is controlled, unless one of the following conditions is complied with:

a. The controller and its disconnecting means is capable of being locked in the open position.

Speed Limitation.—Machines of the following types shall be provided with speed limiting devices, unless the inherent characteristics of the machines, the system, or the load and the mechanical connections thereto, are such as to safely limit the speed, or unless the machine is always under manual control of a qualified operator.

a. Separately excited direct current motors.

b. Series wound motors.

c. Motor-generators and converters which can be driven at excessive speed from the direct current such as by a reversal of current or decrease in load.

Fuseholder Rating.—The rating of a combination fuseholder and switch used as a motor controller shall be such that the fuse holder will accommodate the size of the fuse specified in table 20, page 3,074 for motor running protection.

Disconnecting Means

The following provisions specify disconnecting means for motors and controllers capable of disconnecting them from the circuit. (See diagram fig. 7,360.)

Type.—The disconnecting means shall be a motor circuit switch, rated in horsepower or a circuit breaker except as permitted in the following paragraphs. Every switch in the motor branch circuit within sight of the controller location shall comply with these requirements. A distance of more than 50 feet is considered equivalent to being out of sight.

a. For stationary motors of ⅛ horsepower or less the branch circuit overcurrent device may serve as a disconnecting means.

b. For stationary motors rated at 2 horsepower or less and 300 volts or less, the disconnecting means may be a general use switch having an ampere rating at least twice the full load current rating of the motor.

c. For stationary motors rated at more than 50 horsepower, the disconnecting means may be a motor circuit switch also rated in amperes, a general use switch, or an isolating switch.

It is recommended that isolating switches for motors exceeding 50 horsepower, not capable of interrupting stalled rotor current be plainly marked *Do not open under load.*

d. For portable motors an attachment plug and receptacle may serve as the disconnecting means.

Carrying Capacity.—The disconnecting means shall have a carrying capacity of at least 115 per cent of the name plate current rating of the motor.

Grounded Conductors.—One pole of the disconnecting means may be placed in a permanently grounded conductor if the disconnecting means is so designed that the pole in the grounded conductor cannot be opened without simultaneously disconnecting all conductors of the circuit.

To Be Indicating.—The disconnecting means shall plainly indicate whether it is in the open or closed position.

To Disconnect Both Motor and Controller.—The disconnecting means shall disconnect both the motor and controller from all ungrounded supply conductors. The disconnecting means shall be in the same enclosure with the controller.

Switch or Circuit Breaker as Both Controller and Disconnecting Means.—A switch or circuit breaker complying with the foregoing provisions may serve as both controller and disconnecting means if it opens all ungrounded conductors to the motor, is protected by an overcurrent device (which may be a

set of fuses) which opens all ungrounded conductors to the switch or circuit breaker, and is one of the following types:

a. An air brake switch, operable directly by applying the hand to a lever or handle.

b. A circuit breaker operable directly by applying the hand to a lever or handle.

c. An oil switch used on a circuit whose rating does not exceed 600 volts or 100 amperes, or on a circuit exceeding this capacity if under expert supervision and by special permission.

The oil switch or circuit breaker specified above may be both power and manually operable. If power operable, provision should be made to lock it in the open position.

The overcurrent device protecting the controller may be a part of the controller assembly or may be separate.

A compensator type of controller is not included above and will require a separate disconnecting means.

Service Switch as Disconnecting Means.—If an installation consist of a single motor, the service switch may serve as the disconnecting means, provided it conforms with the foregoing requirements of this chapter, and is within sight of the controller.

In Sight of Controller.—The disconnecting means shall be located within sight of the controller or be arranged to be locked in open position.

Motor Served by a Single Disconnecting Means.—Each motor shall be provided with an individual disconnecting means, except that for motors of 600 volts or less a single disconnecting means may serve a group of motors under any one of the following conditions. The disconnecting means serving a group of motors shall have a rating not less than is required by the foregoing

provisions for a single motor whose rating equals the sum of the horsepowers or currents of all the motors of the group.

a. If a number of motors drive several parts of a single machine or a piece of apparatus such as metal or woodworking machines, cranes and hoists.

b. If a group of motors is under protection of one set of overcurrent devices as permitted by paragraph *a*, page 3,056

c. If a group of motors is in a single room within sight of the disconnecting means.

Readily Accessible.—The disconnecting means shall be readily accessible.

Requirements for Voltages Over 600 Volts

The following provisions recognize the additional hazard due to the use of high voltage. They are in addition to the amendatory of the provisions of this chapter.

Voltages of Over 7,500 Volts.—Motors operating at more than 7,500 volts between conductors shall be installed in fire resistive motor rooms.

Motor Overcurrent Protection.—Running overcurrent protection for a motor of over 600 volts shall consist of either a circuit breaker, or of overcurrent units, integral with the controller which shall simultaneously open all ungrounded conductors to the motor. The overcurrent device shall have a setting as specified elsewhere in this chapter for motor running protection.

Circuit Overcurrent Protection.—Each motor branch circuit and feeder of more than 600 volts shall be protected against overcurrent by one of the following means:

***a*. A circuit breaker of suitable rating so arranged that it can be serviced without hazard.**

b. Fuses shall be of the oil filled or other suitable type. Fuses shall be used with suitable disconnecting means or they shall be of a type which can also be served as the disconnecting means. They shall be so arranged that they cannot be refused or replaced while they are energized.

Disconnecting Means.—The circuit breaker or the fuse as specified in the foregoing paragraph shall constitute the disconnecting means.

Protection of Live Parts; All Voltages

The following provisions specify that live parts shall be protected in a manner judged adequate to the hazard involved.

Where Required.—Exposed live parts of motors and controllers operating at 50 volts or more between terminals, except for stationary motors having commutators, collectors and brush rigging located inside of motor end brackets and not conductively connected to supply circuits operating at more than 150 volts to ground, shall be guarded against accidental contact by enclosure, or by location as follows:

a. By installation in a room or enclosure which is accessible only to qualified persons.

b. By installation of a suitable balcony, gallery or platform, so elevated or arranged as to exclude unqualified persons.

c. By elevation 8 feet or more above the floor.

d. So that it will be protected by a guard rail when the motor operates at 600 volts or less.

Guard for Attendants.—If the live parts of motors or controllers operating at more than 150 volts to ground are guarded against accidental contact only by location as specified in the foregoing paragraph, and if adjustment or other attendance may be necessary during the operation of the apparatus suitable insulating mats or platforms shall be provided so that the attendant cannot readily touch live parts unless standing on the mats or platforms. Where necessary steps and handrails should be installed on or about large machines to afford safe access to parts which must be examined or adjusted during the operation.

Grounding

The following provisions specify the grounding of motor and controller frames to prevent a potential above ground in the event of an accidental contact between live parts and frames. Insulation, isolation or guarding are suitable alternative for motors under certain conditions.

Stationary Motors.—The frames of stationary motors shall be grounded if any of the following conditions exist:

a. If supplied by means of metal-clad wiring.

b. If located in a wet place and not isolated or guarded.

c. If in a hazardous location.

d. If the motor operates with any terminal at more than 150 volts to ground. If the frame of the motor is not grounded it shall be permanently and effectively isolated from the ground.

Portable Motors.—The frames of portable motors which operate at 150 volts to ground shall be guarded or grounded.

It is recommended that the frames of motors which operate at less than 150 volts to ground be grounded if this can be readily accomplished.

Controllers.—Controller cases, except those attached to ungrounded portable equipment and except the lined covers of snap switches, shall be grounded regardless of voltage.

Method of Grounding.—Grounding where required shall be performed as prescribed by the *National Electrical Code*.

Grounding Through Terminal Housing.—If the wiring to fixed motors is in armored cable or metal raceways, junction

boxes to house motor terminals shall be provided. These housings shall be of ample size to properly make connections, they shall be of substantial metal construction, and the armor of the cable or the metal raceway shall be connected to them in accordance with provisions of the *National Electrical Code*.

The foregoing junction box required may be separated from the motor not more than 6 feet, provided the leads to the motor are armored cable or armored cord, or are enclosed in flexible or rigid conduit or electrical metallic tubing not smaller than ⅜ inch electrical trade size, the armor or raceway being connected both to the motor and to the box.

***Example.**—With reference to fig. 7,376, it is required to determine the conductor sizes, the motor running overcurrent protection, the branch circuit protection and the feeder protection for one 25 horsepower squirrel cage motor (full voltage starting) and two 30 horsepower wound rotor induction motors, all connected to a 440 volt, 3 phase 60 cycle system.*

Solution

Conductor Sizes.—The full load current of the 25 horsepower motor is 32 amperes (table 24, page 3,079). A full load current of 32 amperes requires a No. 8 type R, rubber covered conductor (column 2 table 20, page 3,075). The full load current of the 30 horsepower motor is 39 amperes (table 24, page 3,079). A full load current of 39 amperes requires a No. 6 type R rubber covered conductor (column 2, table 20, page 3,075).

The feeder conductor capacity will be 125 per cent of 39 plus 39 plus 32 or 120 amperes, see page 3,049 In accordance with table 1, page 3,070 this would require a No. 0 type R, rubber covered feeder.

Overcurrent Protection

Running.—The 25 horsepower motor, with a full load current of 32 amperes must have a running overcurrent protection of not

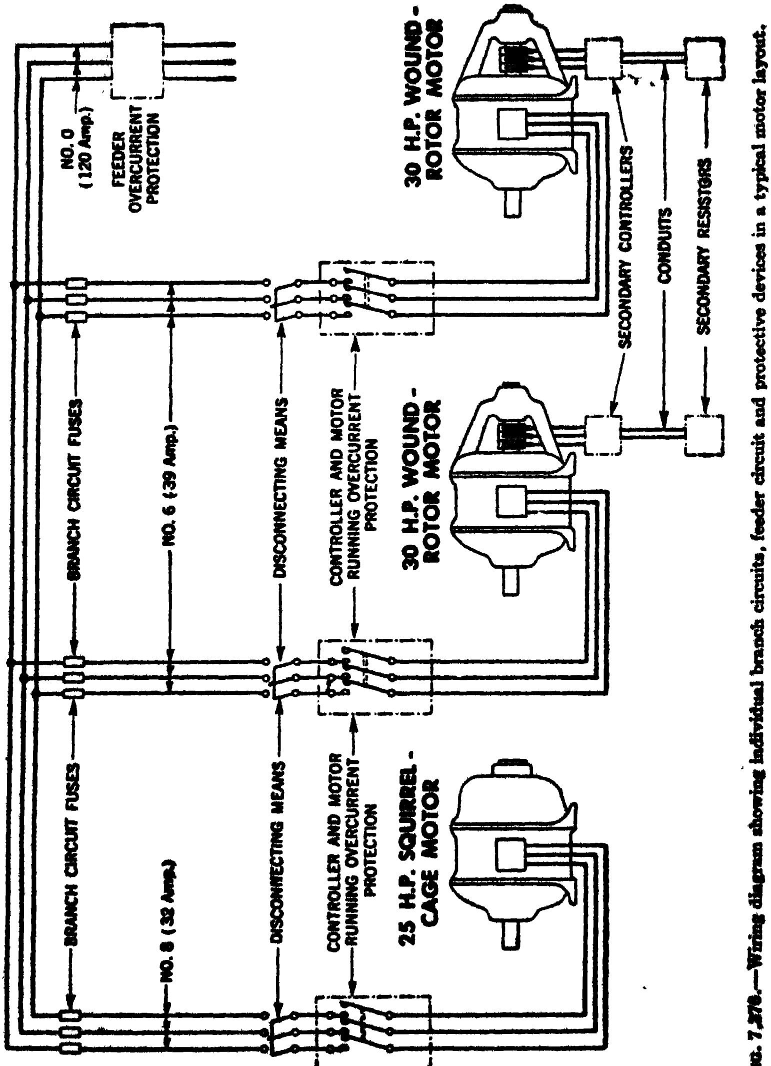


FIG. 7,376.—Wiring diagram showing individual branch circuits, feeder circuit and protective devices in a typical motor layout.

over 40 amperes (columns 5 and 6, table 20, page 3,075). The 30 horsepower must have a running overcurrent protection of not over 50 amperes (columns 5 and 6, table 20, page 3,075).

Branch Circuit.—The branch circuit of the 25 horsepower motor must have a branch circuit overcurrent protection of not over 100 amperes (column 7, table 20, page 3,075). The branch circuit of the 30 horsepower motors must have a branch circuit overcurrent protection of not over 60 amperes (column 10, table 20, page 3,075).

Feeder Circuit.—The rating of the branch circuit fuse for a 25 horsepower squirrel cage motor is 300 per cent of 32 amperes or 96 amperes (table 27, page 3,081); and for a 30 horsepower wound rotor motor is 150 per cent of 39 amperes or 59 amperes (table 27). The rating of a feeder fuse is therefore 96 plus 39 plus 39 or 174 amperes. Therefore a 175 ampere fuse is the maximum size which may be used

The setting of a motor branch circuit breaker for a 25 horsepower squirrel cage motor is 250 per cent of 32 amperes or 80 amperes (table 27), similarly for a 30 horsepower wound rotor motor the setting is 150 per cent of 39 amperes or 59 amperes. The maximum setting of a feeder circuit breaker is 80+39+39 or 158 amperes

TABLE 1—ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES

Not More Than Three Conductors in Raceway or Cable

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14–6) / Thermo-plastic Type T (14–4/0) Type TW (14–4/0)	Rubber Type RH	Paper / Thermo-plastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impreg-nated Asbestos Type AI (14–8) Type AIA	Asbestos Type A (14–8) Type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	...
300	240	285	300	345	380	...
350	260	310	325	390	420	...
400	280	335	360	420	450	...
500	320	380	405	470	500	...
600	355	420	455	525	545	...
700	385	460	490	560	600	...
750	400	475	500	580	620	...
800	410	490	515	600	640	...
900	435	520	555	...	...	...
1,000	455	545	585	680	730	...
1,250	495	590	645	...	...	...
1,500	520	625	700	785	...	...
1,750	545	650	735	...	...	...
2,000	560	665	775	840	...	...

CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C.	F.						
40	104	.82	.88	.90	.94	.95	...
45	113	.71	.82	.85	.90	.92	...
50	122	.58	.75	.80	.87	.89	...
55	131	.41	.67	.74	.83	.86	...
60	140	...	.58	.67	.79	.83	.91
70	158	...	.35	.52	.71	.76	.87
75	167	...	...	.43	.66	.72	.86
80	176	...	...	.30	.61	.69	.84
90	194	...	...	...	.50	.61	.80
100	212	...	...	...	...	.51	.77
120	248	...	...	...	...	...	.69
140	284	...	...	...	...	...	.59

See Notes Following Tables 1 and 2

TABLE 2—ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES

Single Conductor in Free Air

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14–6) / Thermoplastic Type T Type TW	Rubber Type RH	Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14–8) Type AIA	Asbestos Type A (14–8) Type AA	Slow-Burning Type SB / Weatherproof Type WP Type SBW
14	20	20	30	40	40	45	30
12	25	25	40	50	50	55	40
10	40	40	55	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	....	410
300	375	445	480	555	590	....	460
350	420	505	530	610	655	....	510
400	455	545	575	665	710	....	555
500	515	620	660	765	815	....	630
600	575	690	740	855	910	....	710
700	630	755	815	940	1005	....	780
750	655	785	845	980	1045	....	810
800	680	815	880	1020	1085	....	845
900	730	870	940	....	....	....	905
1000	780	935	1000	1165	1240	....	965
1250	890	1065	1130	....	....	....	....
1500	980	1175	1260	1450	....	....	1215
1750	1070	1280	1370	....	....	....	....
2000	1155	1385	1470	1715	....	....	1405
CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.							
C. F.							
40 104	.82	.88	.90	.94	.95	....	....
45 113	.71	.82	.85	.90	.92	....	....
50 122	.58	.75	.80	.87	.89	....	....
55 131	.41	.67	.74	.83	.86	....	....
60 140	....	.58	.67	.79	.83	.91	....
70 158	....	.35	.52	.71	.76	.87	....
75 167	....	....	.43	.66	.72	.86	....
80 176	....	....	.30	.61	.69	.84	....
90 194	....	....	....	.50	.61	.80	....
100 212	....	....	....	....	.51	.77	....
120 248	....	....	....	....	....	.69	....
140 284	....	....	....	....	....	.59	....

See notes following Tables 1 and 2.

TABLE 4—NUMBER OF CONDUCTORS IN CONDUIT OR TUBING

Rubber Covered, Types RF-32, R, RH, RW and RU
Thermoplastic, Types TF, T and TW
One to Nine Conductors

Size AWG MCM	Number of Conductors in One Conduit or Tubing								
	1	2	3	4	5	6	7	8	9
18	½	½	½	½	½	½	½	¾	¾
16	½	½	½	½	½	½	¾	¾	¾
14	½	½	½	½	¾	¾	1	1	1
12	½	½	½	¾	¾	1	1	1	1¼
10	½	¾	¾	¾	1	1	1	1¼	1¼
8	½	¾	¾	1	1¼	1¼	1¼	1½	1½
6	½	1	1	1¼	1½	1½	2	2	2
4	½	1¼	*1¼	1½	1½	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1¼	2	2	2	2½	2½	2½
1	¾	1½	1½	2	2½	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	3	3	3	3½	3½	4
250	1¼	*2½	2½	3	3	3½	4	4	4½
300	1¼	2½	2½	3	3½	4	4	4½	4½
350	1¼	3	3	3½	3½	4	4½	4½	5
400	1½	3	3	3½	4	4	4½	5	5
500	1½	3	3	3½	4	4½	5	5	6
600	2	3½	3½	4	4½	5	6	6	6
700	2	3½	3½	4½	5	5	6	6	...
750	2	3½	3½	4½	5	6	6	6	...
800	2	3½	4	4½	5	6	6	...	...
900	2	4	4	5	6	6	6	...	...
1000	2	4	4	5	6	6	...	...	...
1250	2½	4½	4½	6	6	...	...	...	...
1500	3	5	5	6	...	...	...	...	...
1750	3	5	6	6	...	...	...	...	...
2000	3	6	6	...	...	...	...	...	...

See Note 4 to Tables 1 and 2.

*Where a service run of conduit or electrical metallic tubing does not exceed 50 feet in length and does not contain more than the equivalent of two quarter bends from end to end two No. 4 insulated and one No. 4 bare conductors may be installed in 1-inch conduit or tubing.

TABLE 18—PROPERTIES OF COPPER CONDUCTORS

Size AWG	Area Cir. Mils	Concentric Lay Stranded Conductors		Bare Conductors		D. C. Resistance Ohms/M Ft. At 25 C. 77 F.	
		No. Wires	Diam. Each Wire Inches	Diam. Inches	*Area Sq. Inches	Bare Cond.	Tin'd. Cond.
18	1624	Solid	.0403	.0403	.0013	6.510	6.77
16	2583	Solid	.0508	.0508	.0020	4.094	4.25
14	4107	Solid	.0641	.0641	.0032	2.575	2.68
12	6530	Solid	.0808	.0808	.0051	1.619	1.69
10	10380	Solid	.1019	.1019	.0081	1.018	1.06
8	16510	Solid	.1285	.1285	.0130	.641	.660
6	26250	7	.0612	.184	.027	.410	.426
4	41740	7	.0772	.232	.042	.259	.269
3	52640	7	.0867	.260	.053	.205	.213
2	66370	7	.0974	.292	.067	.162	.169
1	83690	19	.0664	.332	.087	.129	.134
0	105500	19	.0745	.373	.109	.102	.106
00	133100	19	.0837	.418	.137	.0811	.0844
000	167800	19	.0940	.470	.173	.0642	.0668
0000	211600	19	.1055	.528	.219	.0509	.0524
	250000	37	.0822	.575	.260	.0431	.0444
	300000	37	.0900	.630	.312	.0360	.0371
	350000	37	.0973	.681	.364	.0308	.0318
	400000	37	.1040	.728	.416	.0270	.0278
	500000	37	.1162	.814	.520	.0216	.0225
	600000	61	.0992	.893	.626	.0180	.0185
	700000	61	.1071	.964	.730	.0154	.0159
	750000	61	.1109	.998	.782	.0144	.0148
	800000	61	.1145	1.031	.835	.0135	.0139
	900000	61	.1215	1.093	.938	.0120	.0124
	1000000	61	.1280	1.152	1.042	.0108	.0111
	1250000	91	.1172	1.289	1.305	.00864	.00890
	1500000	91	.1284	1.412	1.566	.00719	.00740
	1750000	127	.1174	1.526	1.829	.00617	.00636
	2000000	127	.1255	1.631	2.089	.00539	.00555

* Area given is that of a circle having a diameter equal to the over-all diameter of a stranded conductor.

TABLE 19—DIMENSIONS OF CONDUIT OR TUBING

Size	Internal Diameter Inches	Area Square Inches	Size	Internal Diameter Inches	Area Square Inches
½	.622	.30	3	3.068	7.38
¾	.824	.53	3½	3.548	9.90
1	1.049	.86	4	4.026	12.72
1¼	1.380	1.50	4½	4.506	15.94
1½	1.610	2.04	5	5.047	20.00
2	2.067	3.36	6	6.065	28.89
2½	2.469	4.79			

TABLE 20—CONDUCTOR SIZES AND OVERCURRENT PROTECTION FOR MOTORS. See Tables 26 and 27.

Full load current rating of motor amperes	Minimum size conductor in raceways. For conductors in air or for other insulations see tables 1 and 2. AWG and MCM		For Running Protection of Motors****		Maximum Allowable Rating or Setting of Branch Circuit Protective Devices			
	Type R, Type T	Type RH	Maximum rating of non-adjustable protective devices	Maximum setting of adjustable protective device	With Code Letters: Single-phase and squirrel cage and synchronous. Full voltage, resistor and reactor starting, Code letters F to R inc. Without Code Letters: Same as above.	With Code Letters: Single-phase and squirrel cage and synchronous. Full voltage, resistor or reactor starting, Code letters B to E inc. Auto-transformer starting, Code letters F to R inc. Without Code Letters: Squirrel cage and synchronous, auto-transformer starting, High reactance squirrel cage.*** Both not more than 30 amperes	With Code Letters: Squirrel cage and synchronous Auto-transformer starting, Code letters B to E inc. Without Code Letters: Squirrel cage and synchronous, auto-transformer starting, High reactance squirrel cage.*** Both more than 30 amperes.	With Code Letters: All motors, Code letter A. Without Code Letters: DC and wound-rotor motors.
			Amperes	Amperes				
Col. No. 1	2	3	5	6	7	8	9	10

1**	14	14	2*	1.25*	15	15	15	15
2**	14	14	3*	2.50*	15	15	15	15
3**	14	14	4*	3.75*	15	15	15	15
4**	14	14	6*	5.0 *	15	15	15	15
5**	14	14	8*	6.25*	15	15	15	15
6**	14	14	8*	7.50*	20	15	15	15
7	14	14	10*	8.75*	25	20	15	15
8	14	14	10*	10.0 *	25	20	20	15
9	14	14	12*	11.25*	30	25	20	15
10	14	14	15*	12.50*	30	25	20	15
11	14	14	15*	13.75*	35	30	25	20
12	14	14	15	15.00	40	30	25	20
13	12	12	20	16.25	40	35	30	20
14	12	12	20	17.50	45	35	30	25
15	12	12	20	18.75	45	40	30	25
16	12	12	20	20.00	50	40	35	25
17	10	10	25	21.25	60	45	35	30
18	10	10	25	22.50	60	45	40	30
19	10	10	25	23.75	60	50	40	30
20	10	10	25	25.0	60	50	40	30
22	10	10	30	27.50	70	60	45	35
24	10	10	30	30.00	80	60	50	40
26	8	10	35	32.50	80	70	60	40
28	8	10	35	35.00	90	70	60	45
30	8	8	40	37.50	90	70	60	45
32	6	8	40	40.00	100	80	70	50
34	6	8	45	42.50	110	90	70	60
36	6	8	45	45 00	110	90	80	60
38	6	6	50	47.50	125	100	80	60
40	6	6	50	50.00	125	100	80	60
42	6	6	50	52.50	125	110	90	70
44	6	6	60	55.0	125	110	90	70
46	4	6	60	57.50	150	125	100	70
48	4	6	60	60.0	150	125	100	80
50	4	6	60	62.50	150	125	100	80
52	4	6	70	65.0	175	150	110	80
54	4	4	70	67.50	175	150	110	90

Col. 1	2	3	5	6	7	8	9	10
56	4	4	70	70.00	175	150	120	90
58	3	4	70	72.50	175	150	120	90
60	3	4	80	75.00	200	150	120	90
62	3	4	80	77.50	200	175	125	100
64	3	4	80	80.00	200	175	150	100
66	2	4	80	83.50	200	175	150	100
68	2	4	90	85.00	225	175	150	110
70	2	3	90	87.50	225	175	150	110
72	2	3	90	90.00	225	200	150	110
74	2	3	90	92.50	225	200	150	125
76	2	3	100	95.00	250	200	175	125
78	1	3	100	97.50	250	200	175	125
80	1	3	100	100.00	250	200	175	125
82	1	2	110	103.50	250	225	175	125
84	1	2	110	105.00	250	225	175	150
86	1	2	110	107.50	300	225	175	150
88	1	2	110	110.00	300	225	200	150
90	0	2	110	112.50	300	225	200	150
92	0	2	125	115.00	300	250	200	150
94	0	1	125	117 50	300	250	200	150
96	0	1	125	120.00	300	250	200	150
98	0	1	125	122.50	300	250	200	150
100	0	1	125	125.00	300	250	200	150
105	00	1	150	131.5	350	300	225	175
110	00	0	150	137.5	350	300	225	175
115	00	0	150	144.0	350	300	250	175
120	000	0	150	150.0	400	300	250	200
125	000	00	175	156 5	400	350	250	200
130	000	00	175	162.5	400	350	300	200
135	0000	00	175	169.0	450	350	300	225
140	0000	00	175	175.0	450	350	300	225
145	0000	000	200	181.5	450	400	300	225
150	0000	000	200	187.5	450	400	300	225
155	0000	000	200	194.0	500	400	350	250
160	250	000	200	200.0	500	400	350	250
165	250	0000	225	206.	500	450	350	250
170	250	0000	225	213.	500	450	350	300

175	300	0000	225	219.	600	450	350	300
180	300	0000	225	225.	600	450	400	300
185	300	0000	250	231.	600	500	400	300
190	300	250	250	238.	600	500	400	300
195	350	250	250	244.	600	500	400	300
200	350	250	250	250.	600	500	400	300
210	400	300	250	263.	...	600	450	350
220	400	300	300	275.	...	600	450	350
230	500	300	300	288.	...	600	500	350
240	500	350	300	300.	...	600	500	400
250	500	350	300	313.	...	...	500	400
260	600	400	350	325.	...	...	600	400
270	600	400	350	338.	...	...	600	450
280	600	500	350	350.	...	...	600	450
290	700	500	350	363.	...	...	600	450
300	700	500	400	375.	...	...	600	450
320	750	600	400	400.	...	...	...	500
340	900	600	450	425.	...	...	...	600
360	1000	700	450	450.	...	...	...	600
380	1250	750	500	475.	...	...	...	600
400	1500	900	500	500.	...	...	...	600
420	1750	1000	600	525.	...	...	...	...
440	2000	1250	600	550.	...	...	...	...
460	....	1250	600	575.	...	...	...	...
480	....	1500	600	600.	...	...	...	...
500	....	1500	...	625.	...	...	...	...

TABLE 21—FULL-LOAD CURRENT*
Direct-Current Motors

HP	115V	230V	550V
½	4.6	2.3	....
¾	6.6	3.3	1.4
1	8.6	4.3	1.8
1½	12.6	6.3	2.6
2	16.4	8.2	3.4
3	24.	12.	5.0
5	40	20	8.3
7½	58	29	12.0
10	76	38	16.0
15	112	56	23.0
20	148	74	31.
25	184	92	38.
30	220	110	46.
40	292	146	61
50	360	180	75
60	430	215	90
75	536	268	111
100		355	148
125		443	148
150		584	220
200		712	295

*These values for full-load current are average for all speeds.

TABLE 22—FULL-LOAD CURRENT*
Single-Phase A.C. Motors

HP	115V	230V	440V
1/6	3.2	1.6	
¼	4.6	2.3	
½	7.4	3.7	
¾	10.2	5.1	
1	13.	6.5	
1½	18.4	9.2	
2	24.	12.	
3	34.	17.	
5	56.	28.	
7½	80.	40.	21.
10	100.	50.	26.

For full-load currents of 208 and 200-volt motors, increase corresponding 230-volt motor full-load current by 10 and 15 per cent, respectively.

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

TABLE 24—FULL-LOAD CURRENT*

Three-Phase A.C. Motors

	Induction Type Squirrel-Cage and Wound Rotor Amperes					Synchronous Type †Unity Power Factor Amperes			
HP	110V	220V	440V	550V	2300V	220V	440V	550V	2300V
1/2	4	2	1	.8	—	—	—	—	—
3/4	5.6	2.8	1.4	1.1	—	—	—	—	—
1	7	3.5	1.8	1.4	—	—	—	—	—
1 1/2	10	5	2.5	2.0	—	—	—	—	—
2	13	6.5	3.3	2.6	—	—	—	—	—
3	—	9	4.5	4	—	—	—	—	—
5	—	15	7.5	6	—	—	—	—	—
7 1/2	—	22	11	9	—	—	—	—	—
10	—	27	14	11	—	—	—	—	—
15	—	40	20	16	—	—	—	—	—
20	—	52	26	21	—	—	—	—	—
25	—	64	32	26	7	54	27	22	5.4
30	—	78	39	31	8.5	65	33	26	6.5
40	—	104	52	41	10.5	86	43	35	8
50	—	125	63	50	13	108	54	44	10
60	—	150	75	60	16	128	64	51	12
75	—	185	93	74	19	161	81	65	15
100	—	246	123	98	25	211	106	85	20
125	—	310	155	124	31	264	132	106	25
150	—	360	180	144	37	—	158	127	30
200	—	480	240	192	49	—	210	168	40

For full-load currents of 208 and 200 volt motors, increase the corresponding 220-volt motor full-load current by 6 and 10 per cent, respectively.

*These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

†For 90 and 80 per cent P. F. the above figures should be multiplied by 1.1 and 1.25 respectively.

TABLE 26—MAXIMUM RATING OR SETTING OF MOTOR-BRANCH-CIRCUIT PROTECTIVE DEVICES FOR MOTORS MARKED WITH A CODE LETTER INDICATING LOCKED ROTOR KVA

Type of Motor	Per Cent of Full-Load Current: Fuse Rating (See also Table 20, Columns 7, 8, 9, 10)	Circuit-Breaker Setting: Instantaneous Type	Circuit-Breaker Setting: Time Limit Type
All AC single-phase and polyphase squirrel cage and synchronous motors with full-voltage, resistor or reactor starting:			
Code Letter A	150	—	150
Code Letter B to E	250	—	200
Code Letter F to R	300	—	250
All AC squirrel cage and synchronous motors with auto-transformer starting:			
Code Letter A	150	—	150
Code Letter B to E	200	—	200
Code Letter F to R	250	—	200

Synchronous motors of the low-torque, low-speed type (usually 450 RPM or lower), such as are used to drive reciprocating compressors, pumps, etc., which start up unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 per cent of full-load current.

For motors not marked with a Code Letter, see Table 27.

TABLE 27—MAXIMUM RATING OR SETTING OF MOTOR-BRANCH-CIRCUIT PROTECTIVE DEVICES FOR MOTORS NOT MARKED WITH A CODE LETTER INDICATING LOCKED ROTOR KVA

Type of Motor	Per Cent of Full Load Current: Fuse Rating (See also Table 20, Columns 7, 8, 9, 10)	Circuit-Breaker Setting: Instantaneous Type	Circuit-Breaker Setting: Time Limit Type
Single-phase, all types	300	—	250
Squirrel-cage and synchronous (full-voltage, resistor and reactor starting)	300	—	250
Squirrel-cage and synchronous (auto-transformer starting)			
Not more than 30 amperes	250	—	200
More than 30 amperes	200	—	200
High-reactance squirrel-cage			
Not more than 30 amperes	250	—	250
More than 30 amperes	200	—	200
Wound-rotor	150	—	150
Direct-current			
Not more than 50 H.P.	150	250	150
More than 50 H.P.	150	175	150

Synchronous motors of the low-torque low-speed type (usually 450 R.P.M. or lower) such as are used to drive reciprocating compressors, pumps, etc., which start up unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 per cent of full-load current.

For motors marked with a Code Letter, see Table 26.

Notes (See tables 1 and 2)

1. ***Aluminum Conductors.***—For aluminum conductors, the allowable current-carrying capacities shall be taken as 84% of those given in the table for the respective sizes of copper conductor with the same kind of insulation.

2. ***Bare Conductors.***—If bare conductors are used with insulated conductors, their allowable current-carrying capacity shall be limited to that permitted for the insulated conductor with which they are used.

3. ***Application of Table.***—For open wiring on insulators and for concealed knob-and-tube work, the allowable current-carrying capacities of Table 2 shall be used. For all other recognized wiring methods, the allowable current-carrying capacities of Table 1 shall be used, unless otherwise provided in this code.

4. ***More Than Three Conductors in a Raceway.***—Table 1 gives the allowable current-carrying capacity for not more than three conductors in a raceway or cable. If the number of conductors in a raceway or cable is from 4 to 6, the allowable current-carrying capacity of each conductor shall be reduced to 80% of the values in Table 1. If the number of conductors in a raceway or cable is from 7 to 9, the allowable current-carrying capacity of each conductor shall be reduced to 70% of the values in Table 1.

5. ***Neutral Conductor.***—A neutral conductor which carries only the unbalanced current from other conductors, as in the case of normally balanced circuits of three or more conductors, shall not be counted in determining current-carrying capacities as provided for in the preceding paragraph.

In a 3-wire circuit consisting of two phase wires and the neutral of a 4-wire, 3-phase system, a common conductor carries approximately the same current as the other conductors and is not therefore considered as a neutral conductor.

TEST QUESTIONS

1. *What is the purpose and scope of the National Electrical Code?*

2. *What are the authorities supervising the compliance of the National Electrical Code?*

3. *What are the Code specifications with respect to installation of several motors on one branch circuit?*

4. *Define disconnecting means as required in motor and controller circuits.*

5. *What are the rules for determination of conductor sizes supplying two or more motors?*

CHAPTER 99

Wires and Cables

The wireman who is called upon to plan and install a system of wiring will find it necessary first to have a knowledge of the various kinds of wire so as to select the one best suited for the work, and to be able to make simple calculations in order to determine the proper sizes of wire for the various circuits.

In order to avoid confusion students should be familiar with the following wire and cable definitions, which are taken from the Standards of the A. I. E. E.

Wire and Cable Definitions

Cable.—A stranded conductor (single conductor cable*) or a combination of conductors insulated from one another (multiple conductor cable).

*NOTE.—The first kind of cable is a single conductor, while the second kind is a group of several conductors. The component conductors of the second kind of cable may be either solid or stranded, and this kind of cable may or may not have a common insulating covering. The term cable is applied by some manufacturers to a solid wire heavily insulated and lead covered; this usage arises from the manner of the insulation, but such a conductor is not included under this definition of cable. The term cable is a general one, and in practice, it is usually applied only to the larger sizes. A small cable is called a stranded wire, or a cord, both of which are here defined. Cables may be bare or insulated, and the latter may be armored with lead, or with steel wires or bands.

Concentric Lay Cable.—A single conductor cable composed of a central core surrounded by one or more layers of helically laid wires.

Conductor.—A wire or combination of wires not insulated from one another, suitable for carrying a single electric current.

NOTE.—The term conductor is not to include a combination of conductors insulated from one another, which would be suitable for carrying several different electric currents. Rolled conductors, such as bus bars, are of course, conductors, but are not considered under the terminology here given.

Cord.—A small cable, very flexible and substantially insulated to withstand wear.

NOTE.—There is no sharp dividing line in respect to size between a cord and a cable, and likewise no sharp dividing line in respect to the character of insulation between a cord and a stranded wire. Rubber is used as the insulating material for many classes of cords.

Concentric Strand.—A central core surrounded by one or more layers of helically laid wires or groups of wires.

Bare Cable.—Any group of wires twisted together helically, or composed of any number of such groups. The term wire indicates the individual solid wires in a cable.

FIG. 5,072.—Apparatus Cable. *Used* for connecting machine terminals to brush holders, for transformer leads and similar purposes where great flexibility is required and the working pressure does not exceed 750 volts. One conductor. Sizes up to 2,000,000 c.m. Stranding, extra flexible. Insulation, varnished cambric or rubber compound. Thickness of insulation, same as code standard for 0-600 volt rubber. Covering over insulation, one dry cotton braid. (Sometimes a weatherproof braid is specified.)

Bunched Strand.—Sometimes applied to a collection of straight or twisted wires which are grouped together with little regard to their geometrical arrangement.

Direction of Lay.—The lateral direction in which the strands of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable.

Duplex Cable.—Two insulated stranded conductors twisted together.

NOTE.—Duplex cables may or may not have a common insulating covering.

Factor of Assurance.—The factor of assurance of wire or cable insulation shall be the ratio of the voltage at which it is tested to that at which it is used.

Insulation Resistance.—The electrical resistance in a conductor offered by its insulation, to an impressed voltage tending to produce a leakage of current through the same.

N-Conductor Cable.—A combination of N-conductors insulated from one another.

NOTE.—It is not intended that the name as here given be actually used. Instead, say, 1 conductor cable, 2 conductor cable, 3 conductor cable, etc. In referring to the general case the term "multiple conductor cable" should be used.

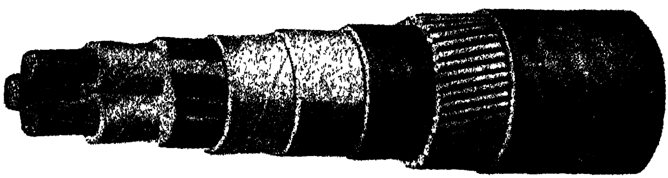


FIG. 5,073.—Armored or submarine cable. *Used* under water for crossing rivers, bays and lakes. Armored cables may be insulated with paper, varnished cambric or rubber compound. The leaded or taped core is served with jute yarn, run through hot asphalt compound, then armored with galvanized steel wires, run through hot asphalt compound, served with two layers of yarn and finally run through asphalt compound. The asphalt and jute over the armor may be omitted, if desired.

FIG. 5,074.—Automobile lighting wire. *Used* for connecting automobile lights with the switch and source of current supply. One wire 10 to 14 *A.w.g.* stranded. Insulation, "Black Core" rubber compound. Covering over insulation, one varnished soft cotton braid 1-64th in. thick. Outside covering one (2 coat) varnished braid, 1-64th in. thick.

N-Conductor Concentric Cable.—A cable composed of an insulated central conductor with (N-1) tubular stranded conductors laid over it concentrically and separated by layers of insulation.

NOTE.—This kind of cable usually has only two or three conductors. Such cables are used particularly for alternating currents. The remark on the expression "N conductor" given for the preceding definition also applies here.

Round Conductor.—Either a solid or stranded conductor of which the cross section is substantially circular.

Rope Lay Cable.—A single conductor cable composed of a central core surrounded by one or more layers of helically laid groups of wires.

NOTE.—This kind of cable differs from the preceding in that the main strands are themselves stranded.

Sector Cable.—A multiple conductor cable in which the cross section of each conductor is substantially a sector, an ellipse, or a figure intermediate between them.

NOTE.—Sector cables are used in order to obtain de ed overall diameter and thus permit the use of larger conductors in a cable of given diameter.

Split Conductor.—A conductor which is divided into two or more parts, separated from one another by insulation which is thin compared with the insulation around the conductor.

FIG. 5,075.—Automobile starting and charging cable. *Used* for connecting the batteries to the starting motor and dynamo, of a gasoline propelled car. One conductor, sizes 2 to 00 *A.w.g.* stranded Insulation, "Black Core" rubber compound. Intermediate covering, one overlapping strip of varnished cambric. Overall covering, one (2 coat) varnished braid, 1-64th in. thick.

FIG. 5.076.—Basket weave armored cable. *It consists of* a wire braid similar in construction to the ordinary cotton braid, used for covering wires. It is usually made of galvanised soft steel wire, but it is sometimes made of brass or copper. The warp and woof of this fabric, each consists of between five and fourteen ends, depending upon the size of cable, the usual size of wire being .0126" diam. The strands or ends are laid closely together, flat and parallel, firmly binding the core. Basket weave is used for two purposes. First as a mechanical protection, and second, as a means of grounding the outside of high voltage cables, in order to prevent static disturbances. The former application is by far the more important.

NOTE.—The term split conductor usually designates a conductor in two parts or splits, which may be either concentric or external to one another.

Strand.—*a*. One of the wires, or groups of wires of any stranded conductor. *b*. Group of single wires in one or more layers, twisted together helically and symmetrically with a uniform pitch around a single central wire or neutral axis. This construction is sometimes called concentric strand.

Stranded Conductor.—A conductor composed of a group of wires, or of any combination of groups of wires.

NOTE.—The wires in a stranded conductor are usually twisted or braided together.

Stranded Wire.—A group of small wires, used as a single wire.

NOTE.—A wire has been defined as a slender rod or filament of drawn metal. If such a filament be subdivided into several smaller filaments or strands, and is used as a single wire, it is called a stranded wire. There is no sharp dividing line of size between a stranded wire and a cable. If used as a wire, for example, in winding inductance coils or magnets, it is called a stranded wire and not a cable. If it be substantially insulated, it is called a cord.

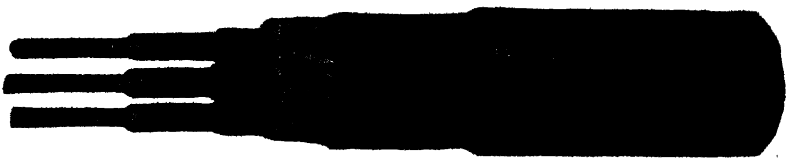


FIG. 5,077.—Border light cable. *Used* for stage lighting or other purposes where a flexible multiple conductor cable is required for electric lights. Number of conductors, three or more. Standard sizes, 12 and 14 *A.w.g.* stranded. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation one saturated braid. Grouping of conductors, twisted. Fillers dry jute. Covering overall, two saturated braids. The outer braid is sometimes saturated with a flameproof compound instead of the usual weatherproof compound.

FIG. 5,078.—Brewery cord. *Used* for extension lights in damp places and differs from ordinary lamp cord only in that the braids are weatherproof instead of dry glazed cotton. Two conductors. Range of sizes, 10 to 18 *A.w.g.* bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Grouping of conductors, twisted pair.

Triplex Cable.—Three insulated single conductor cables twisted together.

Twin Cable.—Two insulated stranded conductors laid parallel, having a common covering.

Twisted Pair.—A cable composed of two small insulated conductors, twisted together, without a common covering.

NOTE.—Triplex cables may or may not have a common insulating covering.

NOTE.—The two conductors of a "twisted pair" are usually substantially insulated so that the combination is a special case of a cord.

Twin Wire.—Two small insulated conductors laid parallel, having a common covering.

Wire.—A slender rod or filament of drawn metal.

NOTE.—The definition restricts the term to what would ordinarily be understood by the term solid wire. In the definition the word slender is used in the sense that the length is great in comparison with the diameter. If a wire be covered with insulation, it is properly called an insulated wire; while primarily the term wire refers to the metal; nevertheless, when the context shows that the wire is insulated, the term wire will be understood to include the insulation.

Standard Annealed Copper.—*a. General.* The following shall be taken as normal values for standard annealed copper.

FIG. 5,079.—Canvasite cord is a type of lamp cord specially adapted to rough usage. Two conductors. Range of sizes, 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Grouping of conductors, twisted. Covering overall, one saturated braid.

b. Resistance.—At a temperature of 20° C., the resistance of a wire of standard annealed copper one meter in length and of a uniform section of 1 square millimeter is 1/58th ohm = 0.017241 ohm.

c. Density.—At a temperature of 20° C., the density of standard annealed copper is 8.89 grams per cubic centimeter.

d. Temperature Coefficient of Resistance.—At a temperature of 20° C., the constant mass temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 per degree centigrade.

e. Resistance of Standard Annealed Copper at 20° C.—As a consequence, it follows from (b) and (c) that, at a temperature of 20° C. the resistance of a wire of standard annealed copper of uniform section, one meter in length and weighing one gram, is 1/58 × 8.89 = 0.15328 ohm.

Copper Wire.—Copper is used in nearly all cases of wiring because it combines high electrical conductivity with good

mechanical qualities and reasonable price. In conductivity it is only surpassed by silver, but the cost of the latter of course prohibits its use for wiring purposes.

Copper wire is used for electric light and power lines, for most telephone and some telegraph lines, and for all cases where low resistance is required at moderate cost.

Hard drawn copper wire is ductile, and has a high tensile strength; these properties allow it to be bent around corners and drawn through tubes without injury.

Pure annealed copper has a specific gravity of 8.89 at 60° Fahr. One cubic inch weighs .32 pound; its melting point is about 2,100° Fahr.

FIG. 5,080.—Car jumper cables. *Used* for connecting the control circuits of adjacent multiple unit cars. They are made flexible to withstand the constant swinging as they stretch from car to car. Number of conductors, five to thirty. Stranding, each conductor consists of 19 No. 24 *A.w.g.* wires. Separator, soft cotton wind. Insulation on each conductor, 30 per cent hevea rubber compound. Insulation thickness of each conductor 3/64". Covering over insulation, one colored dry cotton braid. Fillers, dry jute. Cover over filler, one rubber filled tape. Belt over all conductors, 30 per cent hevea rubber compound. Covering overall, two saturated braids.

Good hard drawn copper has a tensile strength of about three times its own weight per mile length. Thus, a number 10 B. & S. gauge copper wire, weighing 166 lbs. per mile, will have a breaking strength equal to approximately $3\times166=498$ lbs.

Iron Wire.—This kind of wire is largely used for telegraph and telephone lines, although it is rapidly being replaced by copper in long lines.

There are three grades of iron wire:

1. ***Extra best best* (*E. B. B.*)** which has the highest conductivity and is the nearest to being uniform in quality, being both tough and pliable;

2. ***Best best* (*B. B.*)**, which varies more in quality, is not so tough, and is lower in conductivity. *It is frequently sold as E. B. B.*;

3. ***Best* (*B.*)**, which is the poorest grade made, being more brittle, and lowest in conductivity. Iron wire should be well galvanized.

German Silver Wire.—German silver is an alloy, consisting of 18 to 30% nickel, and the balance about four parts copper to one part zinc. It is very largely used as a resistance material in making resistance coils, and is sold in the form of wire and strip. The resistance of this wire varies with its composition.

FIG. 5,081.—Car lighting wire. *Used* for wiring railroad cars illuminated by axle driven dynamos. One conductor. Standard sizes, 0 to 16 *A.w.g.* Insulation, 30 per cent hevea rubber compound. Covering over insulation, 16 to 8 *A.w.g.*, one saturated braid, 6 to 0 *A.w.g.*, two saturated braids.

The resistance of the 18% alloy at 25° C. is 18 times that of copper, and of the 30% alloy about 28 times that of copper.

The safe carrying capacity of the wire in spirals in open air for continuous duty is such that the circular mils per ampere varies from about 1,500 in No. 10 wire to about 475 in No. 30. For intermittent duty the capacity is twice as great.

Standard of Copper Wire Resistance.—Matthiessen's standard for resistance of copper wire is as follows: *A hard drawn copper wire one meter long, weighing one gramme, has a resistance of* .1469 *B. A. unit at* 32° *Fahr.* Relative conducting power: silver, 100; hard or un-annealed copper, 99.95; soft or annealed copper, 102.21.

A committee of the Am. Inst. Electrical Engineers recommends the following form of Matthiessen's standard, taking

8.89 as the specific gravity of pure copper: *A soft copper wire one meter long and one millimeter in diameter has an electrical resistance of* .02057 *B. A. unit at 0°C.** From this the resistance of a soft copper wire one foot long and .001 in. in diameter (mil foot) is 9.72 B. A. units at 0°.C.

For every degree Fahr., the resistance of copper wire increases .2222%. Thus a piece of copper wire having a resistance of 10 ohms at 32° would have a resistance of 11.11 ohms at 82°.

FIG. 5,082.—Single conductor code house wire. *Used* in pairs for house wiring or with twin wires for the neutral of three wire systems. One conductor, sizes, 0000 to 14 *A.w.g.*, solid. Insulation, "Black Core" rubber compound. Covering over insulation one saturated braid, two saturated braids or rubber filled tape and one saturated braid.

Relative Conductivity of Different Metals and Alloys.

(According to Lazare Weiler.)

Pure silver	100	Swedish iron	16
Pure copper	100	Pure platinum	10.6
Alloy, ½ copper, ½ silver	86.65	Copper with 10% nickel	10.6
Telephonic siliceous bronze	35	Pure lead	8.88
Pure zinc	29.9	Pure nickel	7.89
Brass with 35% zinc	21.5	Phosphor-bronze, 10% tin	3.88

Wires.—Copper is used more than any other metal for transmitting electrical energy, and for interior wiring it is used exclusively. Copper conductors should be of the highest commercial conductivity, not less than 97%.

For wires up to sizes as large as No. 8 B. & S. gauge, single wires may be used, but for larger sizes the necessary conductivity should be obtained by conductors made up of strands

*NOTE.—The international ohm ÷ B. A. ohm = 1 ÷ .9866. The B. A. ohm ÷ International ohm = 1 ÷ 1.0136. Hence, to reduce British Association ohms to International ohms, divide by 1.0136, or multiply by .9866.

of smaller wires. The size of these strands depends upon the size of the conductors and the conditions under which they are to be used.

Where conductors are very large (as for instance dynamo leads), and where it is essential that they be as flexible as possible, strands as small as No. 20 or 22 B. & S. gauge may be used.

Conductors for flexible cords, pendants, fixtures, etc., should also consist of very fine strands, so that they may be perfectly pliable and flexible.

FIG. 5,083.—Solid twin (flat) code house wire. *Used* for the same purpose as stranded twin code house wire. Two conductors, sizes 6 to 14 *A.w.g.* Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Grouping of conductors, parallel. Covering overall, one saturated braid.

FIG. 5,084.—Twin flat wire. *Used* for wiring buildings and is useful where it is to be drawn into a conduit with a single conductor cable. Two conductors, sizes, 14 *A.w.g.* to 500,000 *c.m.*, stranded. Insulation on each conductor, "Black Core" rubber compound. Covering ovcr insulation, one saturated braid except for 6 *A.w.g.* and larger where a rubber filled tape is used. Grouping of conductors, parallel. Covering overall, one saturated braid.

The individual strands for instance, for a No. 16 B. & S. gauge flexible cord should be as fine as No. 30.

NOTE.—Copper, aluminum and steel are the only materials in common commercial use for electric wires. The low conductivity and large size of aluminum and steel wires compared to copper, however, so increase the cost of insulation as to render their use in insulated wires, except in very special cases, inadvisable and uneconomical. Copper for electrical purposes should be absolutely pure as a very small amount of any impurity seriously affects the electrical conductivity.

Covered Conductors.—For most conditions of service, wires are protected with an insulating covering. Wires used in interior circuits should have a covering which shall act both as an electrical insulator and as a mechanical protection. In some instances, however, the insulating qualities are of secondary importance.

The various forms of covering now in use commercially for wires are:

1. Rubber;
2. Weather proof;

FIG. 5,085.—Fixture wire. *Used* in wiring electric light fixtures. One conductor, standard sizes, 16 and 18 *A.w.g.*, solid or stranded. Insulation, "Black Core" rubber compound. Covering over insulation, one saturated braid, at least 1/64" thick.

FIG. 5,086.—Deck cable is a portable cable for rough usage in damp places. Two (untinned) conductors, sizes 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Fillers, dry jute. Grouping of conductors, twisted. Insulating belt, "Black Core" rubber compound. Thickness of belt, 1/64". Covering overall, one saturated braid.

3. Slow burning;
4. Slow burning weather proof;
5. Armored

Rubber Covered Conductors.—This class of conductor consists of a tinned copper wire with a rubber covering, protected by an outside braiding of cotton saturated with a preservative compound.

Ques. What are the advantages of rubber insulation for wires?

Ans. It is water proof, flexible, fairly strong, and has high insulating qualities.

Ques. What are the disadvantages of rubber insulation?

Ans. It deteriorates more or less rapidly and is quickly injured by temperatures above 140° Fahr.

Ques. For what service are rubber covered conductors adapted?

Ans. For interior wiring.

FIG. 5,087.—Flame proof cable. *Used* about power houses in the vicinity of switchboards and apparatus where special fire proof protection is desired. This method of protection consists essentially in impregnating the braided covering with a flame proof paint, and may be used in connection with any conductors having braided covering, when so specified.

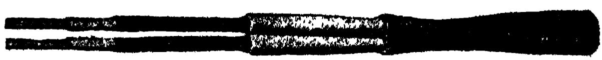


FIG. 5,088.—Heater cord. *Used* for the wiring of domestic heating apparatus, such as flatirons, stoves, etc., requiring over 250 watts. Two untinned conductors, sizes 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one asbestos braid. Grouping of conductors, twisted. Covering overall, one glazed cotton braid.

Ques. Is pure rubber used?

Ans. No. The covering should be made from a compound containing from 20 to 35 per cent. of pure rubber.

It would be difficult to place pure rubber on a wire, and moreover a covering made of pure rubber would not be durable and would deteriorate

NOTE.—*Tinning.*—Perfect tinning of the copper conductor for all rubber covered wires is absolutely necessary to insure great durability. The coating of the pure tin protects the copper from the action of the sulphur used and the minutest flaw in this coating will allow a chemical action to begin and the conductor will be gradually eaten away.

very rapidly, particularly at temperatures above 120° Fahr. Accordingly, it is mixed with other materials, such as French chalk, silicate of magnesia, sulphur, red lead, etc.

Weather Proof Wires.—This class of wire is protected from the weather by a water proof covering, consisting usually of braided cotton of two or three thicknesses saturated with a moisture resisting insulating compound.

Ques. Where are weather proof conductors used?

FIG. 5 089.—Lamp cord. *Used* for pendants in dry places and also for portables in dry places where the usage is not hard. Two untinned conductors, sizes 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one silk cotton, or mercerized cotton braid. Grouping of conductors, twisted pair. The braid is made in all standard colors.

FIG. 5,090.—Third rail jumpers are used for joining sections of third rail at cross-overs, section gaps, and similar places where the third rail is discontinuous. One conductor, sizes 2,000,000 to 250,000 *c.m.* Insulation, 20 per cent hevea rubber compound. Covering over insulation, one rubber filled tape. Covering over tape, jute serving. Covering over jute, two saturated braids.

Ans. In places subject to dampness, such as cellars, tunnels, open sheds, etc.

Ques. What are the advantages of weather proof wire?

Ans. The insulation is cheap, very durable, and does not deteriorate unless exposed to high temperatures such as will melt the compound.

Ques. State the disadvantages.

Ans. The covering is more or less inflammable and is not very efficient as an insulator.

Ques. What precaution should be taken in using weather proof wires?

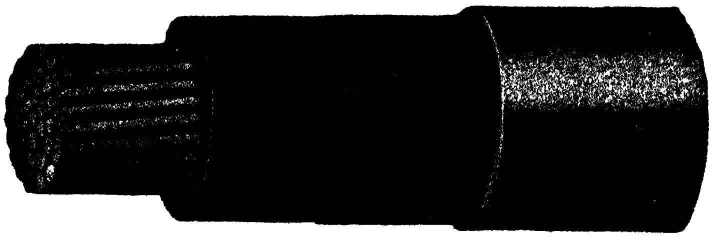


FIG. 5,091.—Stranded single conductor lead covered cable is similar to solid single conductor lead covered wire except that it has greater flexibility and is made in larger sizes. One conductor, sizes, 14 *A.w.g.* to 2,000,000 *c.m.* stranded. Insulation, "Black Core" rubber compound. Covering, one rubber filled tape or braid. Covering overall, lead sheath.

FIG. 5,092.—Three conductor lead covered cable, solid. *Used* for three-phs circ [illegible] der the same conditions of service as single conductor solid lead covered wire. Three conductors, sizes to 14 *A.w.g.* solid. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one rubber filled tape. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, lead sheath.

Ans. On account of the inflammable character of the covering, care should be taken in wiring at points where any considerable number of wires are brought together, or where there is much wood work or other combustible material.

Ques. For what use are weather proof wires especially adapted?

Ans. For outside wiring where moisture is certain and where fire proof quality is not necessary.

Obviously wires of this class should not be used in conduits, nor in fact, in any way except exposed on glass or porcelain insulators.

Slow Burning Wire.—This class of wire is defined as: *one that will not carry fire.* The covering consists of layers of cotton or other thread, all the interstices of which are filled with

FIG. 5,093.—Solid single conductor lead covered wires. *Used* where conditions require a moderate degree of mechanical protection or insurance against the penetration of moisture, or both, as in outdoor ducts and manholes in wet locations. One conductor, sizes 4 to 14 *A.w.g.* solid. Insulation, "Black Core" rubber compound. Covering over insulation, one rubber filled tape or braid. Covering overall, lead sheath.

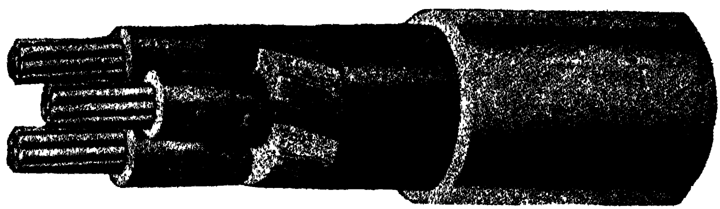


FIG. 5,094.—Three-conductor lead covered cable, stranded. *Used* for three-phase circuits where extra flexibility is required in the smaller sizes and always in the larger sizes where solid conductors would make the cable too stiff to handle. Three conductors, sizes 0000 to 14 *A.w.g.* Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one rubber filled tape. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, lead sheath.

the fireproofing compound, or of material having equivalent fire resisting and insulating properties. The outer layer is braided and specially designed to withstand abrasion. The thickness of insulation must not be less than that required for slow burning weather proof wire and the outer surface must be finished smooth and hard.

Ques. Where should slow burning wires be used?

Ans. In hot dry places, where ordinary insulations would be injured, and where wires are bunched, as on the back of a large switchboard or in a wire tower.

A slow burning covering is considered good enough when the wires are entirely on insulating supports. Its main object is to prevent the copper conductors coming into contact with each other or anything else.

Ques. What must be done before using weather proof wire?

FIG. 5,095.—Concentric mine cable. This is used for the reels of gathering reel locomotives and for cutting machines. It has the advantage of being round and of small diameter. Two conductors. Stranding of center conductor, flexible. Stranding of outer conductor, ring of wires having total cross sectional area equal to that of center conductor. Covering of center conductor, rubber filled tape. Covering over outside conductor, belt of "Black Core" rubber compound. Covering over belt, rubber filled tape. Covering over tape, two extra tight water proof braids.

FIG. 5,096.—Packinghouse cord is flexible lamp cord made to withstand rough usage in damp places. Two untinned conductors, sizes 10 to 18 *A.w.g.* bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated cotton braid. Grouping of conductors, twisted pair. Fillers, dry jute. Covering overall, 2 saturated cotton braids.

Ans. Permission to use the wire must first be obtained from the local Inspection Department.

Slow Burning Weather Proof Wire.—The covering of this type wire is a combination of the Underwriters' and weather proof insulations. The fireproof coating comprises a little more than half of the total covering. When the fireproof coating is placed on the outside, the wire is called "slow burning weather proof."

Ques. How does slow burning weather proof wire compare with weather proof wire?

Ans. It is less inflammable and less subject to softening under heat.

Ques. Where should slow burning weather proof wire be used?

Fig. 5,097.—Park Cable. *Used* for transmission and distribution where it is preferable to bury the cables directly in the ground rather than to put them in ducts. Any kind of cable will be furnished with park cable covering, but the following types are in general use for distribution purposes. Standard park cables (0-600 volts). One to three conductors. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, rubber filled tape. Covering over tape, lead sheath. Covering over lead sheath, asphalted jute. Protective armor, two galvanized steel tapes, wound in the same direction, the outer tape covering the spaces between turns of the inner tape. Outside covering, asphalted jute.

Fig. 5,098.—Paper insulated cables. *Used* for underground transmission and distribution, for which they have the advantages of cheapness, durability, low dielectric losses, low electrostatic capacity and high current-carrying capacity. The insulation consists of Manila paper applied helically to the conductor, and then saturated with a mineral oil compound which constitutes the essential insulation. In order to retain this oil the cable must have an oil-proof covering which is almost invariably a sheath of lead. Sizes from No. 6 *A.w.g.* to 2,000,000 *c.m.*, and with any number of conductors within the usual l

Ans. In places where the wires are to be run exposed and where moisture resisting quality is desired, also where at the

same time it is desirable to avoid an excess of inflammable covering.

Ques. How should it be installed?

Ans. It should be set on glass or porcelain insulators.

Ques. For what service is slow burning weather proof wire not suited?

Ans. It is not adapted to outside work.

FIG. 5,099.—Rubber insulated signal wire for 660 volts or less. One or two conductors, sizes 0 to 18 *A.w.g.*, solid. Insulation on each conductor, Railway Signal Association compound. Covering over insulation, one cotton braid, 3/64" thick, weather proof.

FIG. 5,100.—Reinforced cord. *Used* in dry places for portable lamps, fans, heavy pendants and other electric devices for which type C Lamp Cords are inadequate. Two untinned conductors, sizes 10 to 18, *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one soft cotton braid. Grouping of conductors, twisted. Insulating belt, "Black Core" rubber compound. Covering over belt, one glazed cotton braid.

Stranding.—If a solid copper wire be made larger in diameter than .46 in. it becomes hard to splice and difficult to handle, owing to its size and stiffness. Conductors larger than this are nearly always built up of small wires twisted into a strand or cable. The flexibility of a cable will increase as the size of the constituent wires decreases or as the number of wires increases, and it will depend somewhat upon the method of laying up the cable.

While it is possible to build up a cable from any number of

wires, there are certain combinations only that can be used to obtain a smooth and symmetrical cable. These combinations are governed by well established geometrical rules which should be observed whenever possible.

There are in general use in the United States two methods of specifying stranded conductor. The first and older method specifies a number of strands of such a size as to equal a regular gauge size or a round number of circular mils, such as

FIG. 5,101.—Station cable. *Used* for connecting apparatus and machinery in power stations and sub-stations. One conductor, sizes 2,000,000 to 250,000 *c.m.* Insulation, varnished cambric. Thickness of insulation, depends upon voltage and method of installation. Covering over insulation, one saturated cotton braid, and one flameproof braid.

FIG. 5,102.—Stage cable. *Used* for the operation of movable lamps on theatre stages. Two untinned conductors, sizes 10 to 14 *A.w.g.*, bunched and 4 to 8 *A.w.g.*, rope stranded. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated cotton braid. Grouping of conductors, twisted. Fillers, dry jute. Covering overall, two saturated cotton braids.

250,000, 500,000, 1,000,000, etc. This method is objectionable as it almost invariably necessitates an odd size strand, causing delay in delivery and in some cases increased cost. The second method specifies a number of strands each of a standard gauge size. This method is preferable, and while it does not give stranded conductors equivalent to even gauge sizes, it is near enough for all practical engineering purposes.

Stranded conductors may either be concentric lay or rope lay. Concentric lay is commonly used where the number of strands is less than 127

and rope lay where it is more. The flexibility of a stranded conductor depends on the number of strands, not on the method of lay, *i.e.*, concentric or rope.

The best concentric stranding is made by using one wire as a center and twisting around it six wires constituting the first layer, then a layer of 12 wires, then 18, 24, 30, 36, etc., each layer being twisted in the opposite direction from the preceding. Centers of 3 or 4 wires may also be used.

In rope stranding the groups forming the rope are laid as concentric

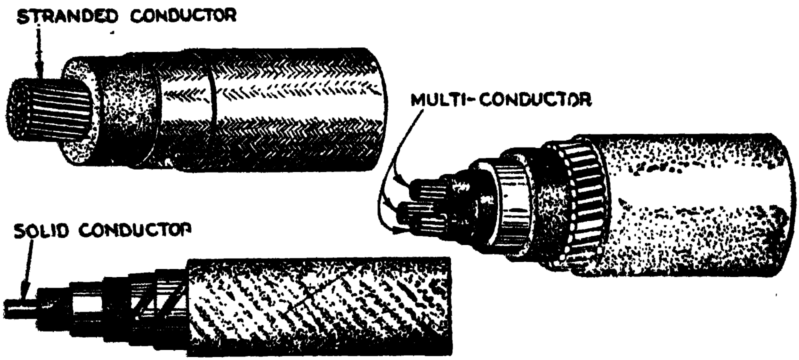


FIG. 5,103.—Stranded single conductor double braided station cable.
FIG. 5,104.—Stranded multi-conductor band steel armored park cable.
FIG. 5,105.—Solid single conductor band steel armored park cable.

strands, and these strands may then be handled as individual wires are in concentric stranding. The number of combinations on rope lay are almost innumerable, but the series 7×7−7×19−7×37, etc. 19×19−19×37, etc. 27×37−37×61, etc., are the best. The term "bunching" or "bunched stranding" is applied to a collection of strands laid without regard to their geometrical arrangement. These wires are sometimes laid straight and held together with a wind or braid of cotton, or they are twisted together in a mass. The only excuse for this method of so-called stranding is cheapness.

The following table gives the number of wires in concentric stranding (or the groups of wires in rope stranding) using

centers of 1, 3 or 4; also multipliers to obtain the outside diameter of the conductor.

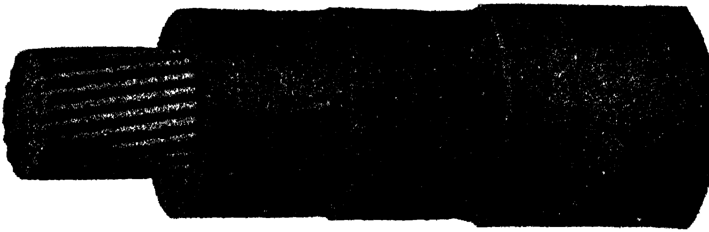


FIG. 5,106.—Single conductor stranded code house cable. *Used* in pairs for house wiring, or with twin wires for the neutral of three wire systems. One conductor. Sizes, No. 14 *A.w.g.*, and all larger sizes, stranded. Insulation "Black Core" rubber compound. Covering over insulation, one saturated braid, two saturated braids or rubber filled tape and one saturated braid.

Number of Wires in Concentric Stranding

(According to Okonite)

Center of 1		Center of 3		Center of 4	
Number of Strands	Multiplier	Number of Strands	Multiplier	Number of Strands	Multiplier
1	1	3	2.1547	4	2.414
7	3	12	4.1547	14	4.414
19	5	27	6.1547	30	6.414
37	7	48	8.1547	52	8.414
61	9	75	10.1547	80	10.414
91	11	108	12.1547	114	12.414
127	13	147	14.1547	154	14.414
169	15	192	16.1547	200	16.414
217	17	243	18.1547	252	18.414

Examples:

Concentric Stranding.

Find diameter of conductor having:

37 strands No. 14 A.w.g. (.06408")

Diameter = 7 × .06408" = .4486".

Table can also be used for multiple conductor cable, as follows:

Rope stranding:

Find diameter of conductor having:

7×19 (133) strands of No. 14 A. W. G. (.06408″)

$$\text{diameter} = 3 \times 5 \times .06408'' = .9612''$$

Find diameter over conductors of a multiple conductor cable consisting of 27 No. 14 *A.w.g.* solid, each with 3/64″ wall insulation plain:

$$\text{No. } 14 = .06408''$$
$$\text{Insulation, } \tfrac{3}{64}'' \times 2 = .09375''$$
$$\text{Diameter over insulated conductor} = .15783''$$
$$\text{Diameter over conductors} = 6.1547 \times .158'' = .9724''.$$

To obtain the outside diameter of the finished cable, addition must be made for tape, braid, lead or armor.

Due to the twist in the strands the weight of a stranded wire is greater than the equivalent solid wire. The resistance is also greater, as the current apparently follows the strands instead of flowing parallel with the axis of the wire.

FIG. 5,107.—Code house cable, three conductor solid. *Used* for wiring buildings especially for use with three phase machinery. Three conductors. Sizes, 20 to 14 *A.w.g.* **Insulation** on each conductor, "Black Core" rubber compound. Covering over insulation, 2 to 6 *A.w.g.*, one rubber filled tape, 8 to 14 *A.w.g*, one saturated braid. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, one saturated cotton braid.

FIG. 5,108.—Three-conductor stranded code house cable. *Used* under the same conditions as solid three conductor code house cable unless greater flexibility is required, especially in the larger sizes. Three conductors, sizes 0000 to 14 *A.w.g.*, stranded. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, 0000 to 6 *A.w.g.*, one rubber filled tape, 8 to 14 *A.w.g.*, one saturated braid. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, one saturated braid.

The generally accepted figures for increase of both weight and resistance over solid wire are 2% for concentric and 4.04% for rope stranding.

Cables.—By definition a cable is a single copper wire, or strand of such wires, heavily insulated and covered by a coated metal sheath or envelope, for the purpose of telegraphic communication or electrical distribution. There are numerous kinds of cables designed to meet the varied requirements. With respect to the conductor, cables may be classed as

1. Single conductor;
2. Multi-conductor.

The classification refers to the number of electrical paths and not the number of wires. Thus a single conductor cable may have only one large wire or for flexibility, the conductor is composed of a number of fine wires grouped together, stranded and covered by an outer insulation.

A multi-conductor cable consists of a number of individually insulated wires (either solid or stranded) which may or may not be grouped together within an outer covering.

Sometimes an outer sheath of lead, steel wires or bands is placed over the cable.

The term "cable" is a general one, and in practice, it is usually applied only to the larger sizes.

A small cable is called a stranded wire or a cord. A stranded wire is a group of small wires, used as a single wire. A cord is a small flexible insulated cable.

A stranded wire may or may not be insulated. A cord must be insulated. There is no sharp dividing line of size between a cable and a stranded wire, or between a stranded wire and a cord.

The accompanying cuts show the classification above mentioned.

132,000 Volt Single Conductor Oil Filled Cable.—While the power generated from local plants in heavy centers of industry and population is distributed locally at about 13,000 or 25,000 volts, system interconnection lines and long distance transmission lines require considerably higher pressures in the order of 66,000, 132,000 and 220,000 volts.

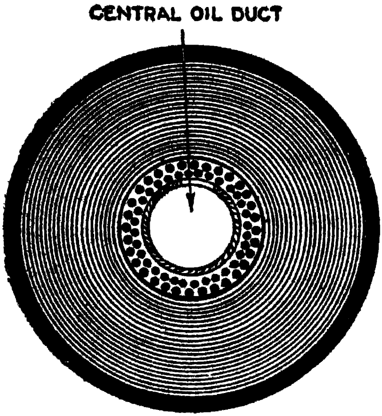
In most situations of heavily built up centers, it has been impossible in the past to tie the higher voltage lines directly to the distributing stations and substations, and recourse has been made to underground cable lines of 33,000, 45,000 and 66,000 volts connecting to the higher voltage overhead lines through transformers located at substations on the outskirts of the city.

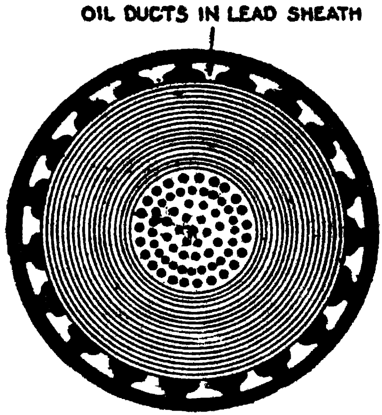
One of the principal aims of the design of the new type or oil filled cable, which by one step doubles the highest underground operating voltage used heretofore, is to do away with these outside intermediate substations by bringing the higher voltages directly to the ultimate distributing centers. The economic and operating advantages thereby obtainable are savings of intermediate substations, transformers, switch gear and attendance, reduction in number of underground cables, savings in synchronous condensers increased efficiency, improved regulation and improved stability of parallel operation of local plants with the outside sources of power.

The final relative values of these savings will not be available until there is secured from actual experience the relative carrying capacity of the oil filled cables in contrast with the ordinary type of cables with solid insulation.

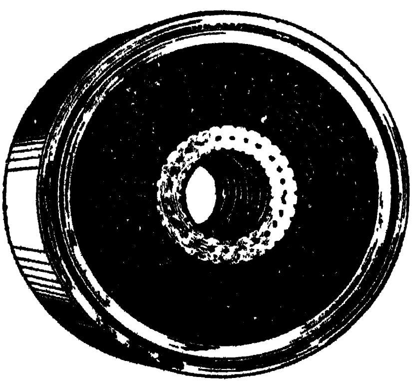
The theory of the oil filled cable is that *through its collapsible oil reservoirs it responds readily to volumetric changes in oil and cable due to temperature changes.*

In this manner, the whole cable is kept constantly filled with oil under pressure both in the hollow core of the conductor and throughout the surrounding insulation. The unique advantage of this type of construction, therefore, is that should the lead sheath be expanded or distorted, or the





FIGS. 5,109 and 5,110 —Two types of oil insulated cable. Fig. 5,109, central oil duct; fig 5,110, oil ducts in lead sheath.



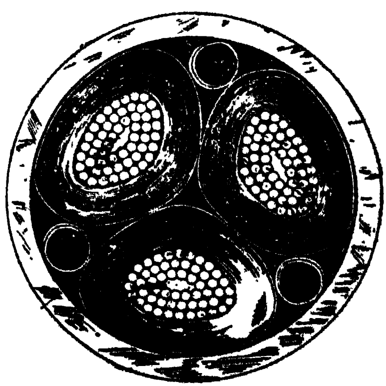


FIG. 5,111.—General Electric single conductor 132,000 volt cable showing construction.

FIG. 5,112.—General Electric three conductor 45,000 volt oil filled cable.

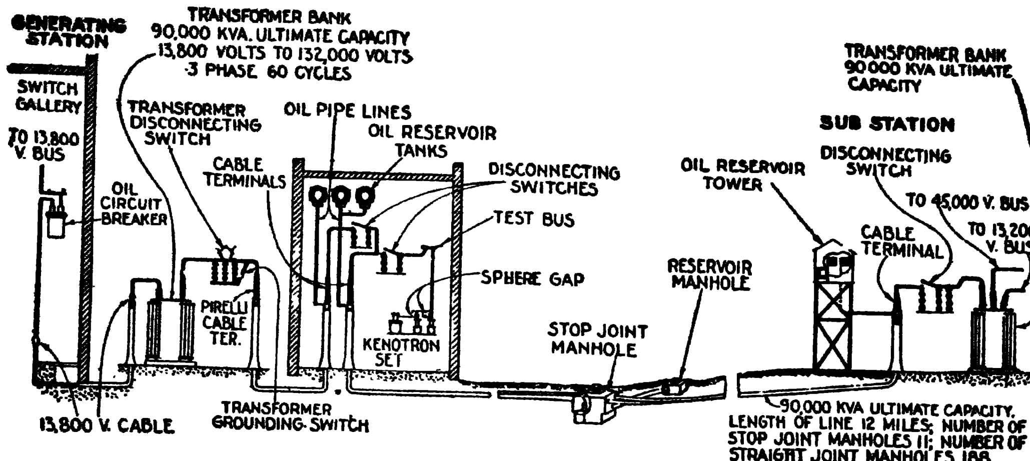


Fig. 5,113.—Diagram of oil insulated cable installation showing transformer banks, 90,000 ***kva.*** **ultimate capacity; 13,800 volts to 132,000 volts, three phase, 60 cycles.**

internal elements of the cable be displaced by temperature variation or other causes, the spaces thus formed will be immediately filled with oil, while in a solid insulation type voids would be formed, causing ionization and ultimate failure. It is thus evident that this new type of cable should be able to operate safely over a much larger range of copper temperature and therefore of load than a solid insulation type, even if the latter be operated at only 66,000 volts or less.

The principle is simple and consists in ***having the cable connected to a reservoir which will receive the oil pushed out during the thermic expansion and give it back to the cable during the contraction.***

To obtain this action, it is necessary to have inside the cable a passage which connects the reservoir with every point of the dielectric. This feature can be obtained readily by stranding the copper wires of the conductor around a metal spiral, thus leaving a single central passage, as in fig. 5,109, or by shaping the lead sheath as in fig. 5,110, thus making several longitudinal paths which can be connected to the reservoir. This eliminates the danger of formation of empty spaces due to the contraction of the oil.

The presence of a longitudinal path makes possible the evacuation and impregnation of the cable from both ends after it has been leaded. On account of its small volume, laboratory pumps can be used and a high

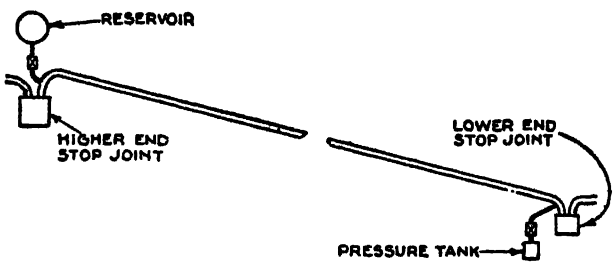


FIG. 5,114.—Diagram of one section of oil filled cable showing reservoir, pressure tank stop, joints, etc.

vacuum reached. In addition to this, a special process has been worked out to purify the oil from the gases in solution, before impregnating the paper. In this way it is possible to obtain a cable practically without any occluded gas from the start and also to maintain it in such condition during operation.

The pressure tank as shown in fig. 5,114, consists of a strong metal tank full of oil which has inside a certain number of air tight cells, with collapsible walls, full of gas. The tank is connected with the lower end of the cable and for this reason the oil in it and the gas inside the cells are subjected to the pressure corresponding to the static head of oil from the reservoir.

When the cable cools down, the pressure at the far end of the section drops below the static head and the gas enclosed in the collapsible cells increases in volume, and pushes out the oil from the tank into the cable.

At the first moment of cooling, the pressure tank is subjected to a hydrostatic pressure given by the head of oil from the feeding reservoir, and acts

exactly as an open tank connected at the lower end of the section, at the same level as the feeding tank. In this first moment, therefore, half of the cable will be fed by the feeding tank and half by the pressure tank, but after a certain length of time, the pressure inside the tank and in the gas cells will be smaller on account of the volume of oil having been fed back to the line.

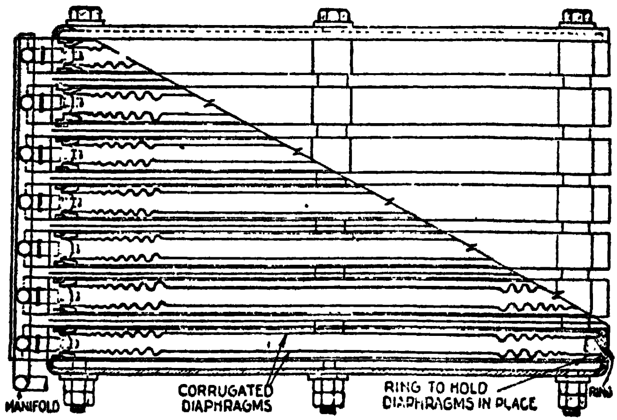


FIG. 5,115.—Feeding tank for oil filled cable.

Each standard section of the line consists essentially, as shown in fig. 5,114, of: 1, two stop joints which close the central oil passage in such a way that the oil of one section has no connection with the oil of the next section; 2, one set of feeding tanks which gives oil to the cables; and 3, in certain special conditions, a pressure tank which supplements the oil supply to the cable.

TEST QUESTIONS

1. *What is a cable?*
2. *Define the term conductor.*
3. *What are the desirable features of copper which makes its use valuable for wires?*
4. *For what services are copper wires used?*

5. *What kind of wire is used for telegraph and telephone lines?*
6. *For what is German silver wire used?*
7. *Give Matthiessen's standard for resistance of copper wire.*
8. *State the relative conductivity of different metals and alloys.*
9. *What metal is used most for wires?*
10. *When are stranded conductors used instead of single conductors?*
11. *What protection is given to wires for most conditions of service?*
12. *Name the various forms of covering for wires.*
13. *What are the advantages of rubber insulation for wires?*
14. *What are weather proof wires, and where are they used?*
15. *What is a slow burning wire?*
16. *How does slow burning weather proof wire compare with weather proof wire?*
17. *Where should slow burning weather proof wire be used?*
18. *Is it possible to build up a cable from any number of wires?*
19. *Name two methods of specifying stranded conductor.*
20. *Is the weight of a stranded wire greater than that of the equivalent solid wire and why?*
21. *What is an oil filled cable and what is the oil used for?*
22. *Describe theory of the oil filled cables.*
23. *Are oil filled cables used for low or high voltage?*

24. *What are the highest voltages used for power transmission by means of cables?*

25. *What is meant by the term "sector cable"?*

26. *What is a duplex cable?*

27. *How are cables generally classified?*

28. *State the advantage and disadvantages of weather proof wire.*

CHAPTER 100

Joints and Taps

The author objects to the careless and erroneous use of the terms *joints* and *splices*. There is considerable difference between a *joint* and a *splice*.

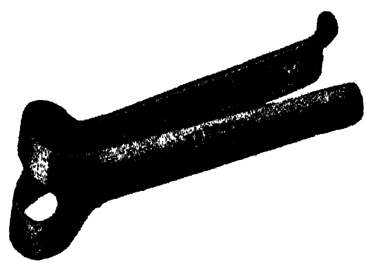


Fig. 5,116.—Martindale insulation scraper.

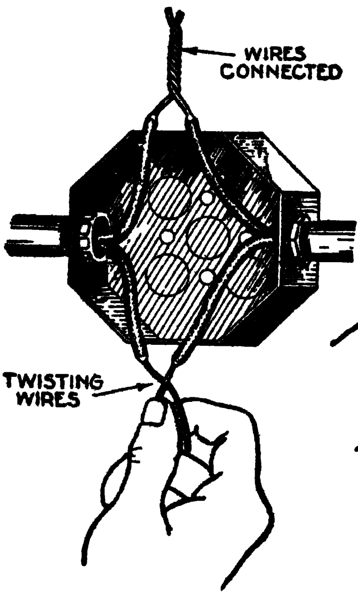
Fig. 5,117.—Austin cable ripper for removing outer braid.

By definition a joint is ***the tying together of two single wire conductors so that the union will be good both mechanically and electrically.***

A splice is the interlaying of the strands of two stranded conductors so that the union will be good both mechanically and electrically.

Making a joint tap or splice comprises the operations of

1. Removing the insulation;
2. Cleaning the conductors;
3. Tying, or interlaying;



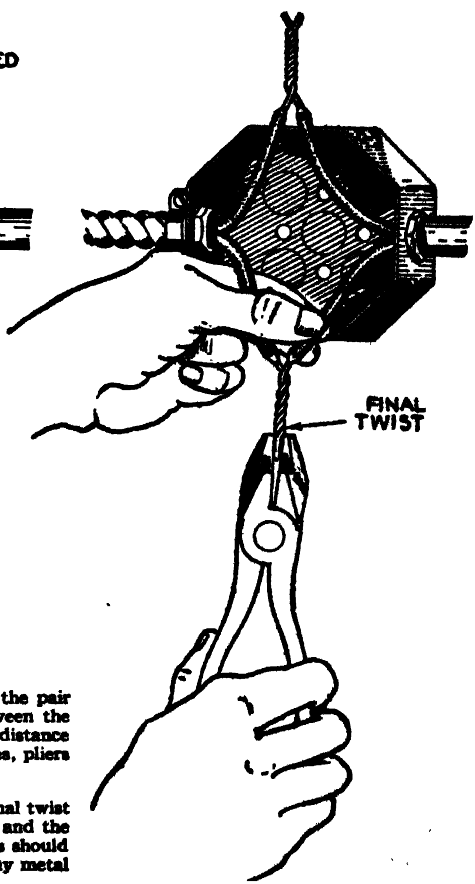


FIG. 5,118.—*Pig tail joint 1.* Cross the pair of conductors to be connected between the fingers and twist them together for a distance of at least an inch. For heavy wires, pliers must be used.

FIG. 5,119.—*Pig tail joint 2.* The final twist must be made with a pair of pliers and the excess wire cut off. The bare joints should now be pulled out of contact with any metal so that the circuit may be tested.

4. Soldering;
5. Tap(e)ing.

The subjects of splices, soldering and tap(e)ing are taken up in separate chapters.

Removing the Insulation.—In preparing insulated conductors for making joints or splices, the insulation must first be removed from each conductor a proper distance depending upon the type joint or splice to be made.

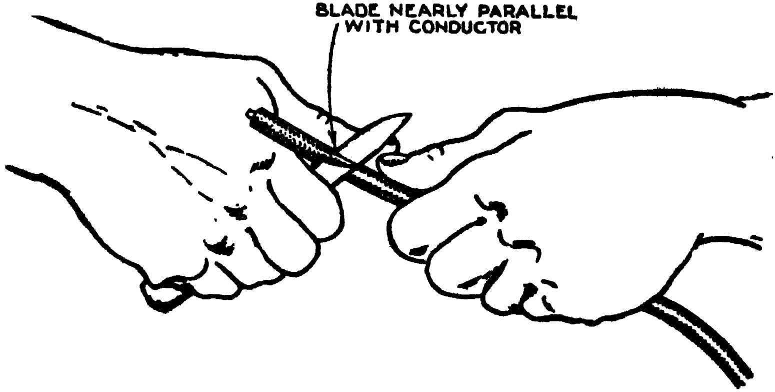


FIG. 5,120.—Method of using knife in stripping insulation. Hold the blade so that it will lie flat with the wire to avoid nicking the latter. Stripping with a knife is not recommended

This process is sometimes called *skinning* or *stripping*. This operation is usually performed in a questionable manner by the use of an ordinary knife blade resulting in loss of time and probable nicking of the wire.

For a single wire conductor a form of scraper such as shown in fig. 5,116 should be used.

The method of using a ripper (fig. 5,117) is shown in fig. 5,121. The insulation of a duplex cable should first be ripped with a tool stick; then the insulation from the separate conductors is removed with a scraper.

If a knife must be used, do not cut insulation crosswise the wire, but parallel with the wire as in fig. 5,120.

Cleaning the Conductors.—After removing the insulation, the wires must be thoroughly cleaned to insure good electrical

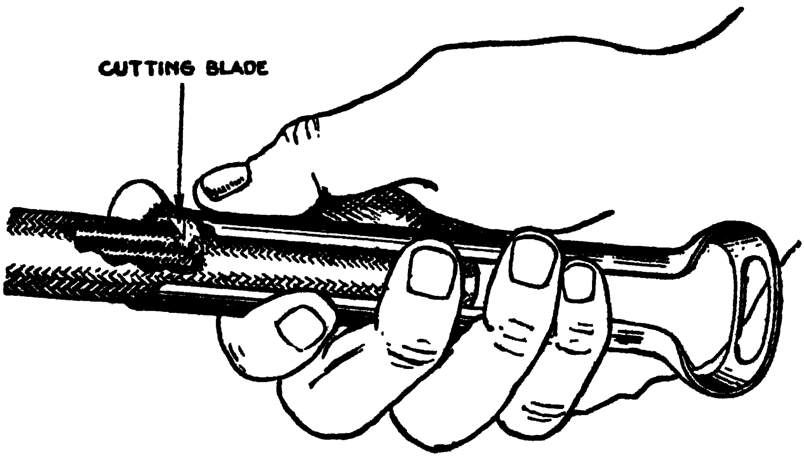
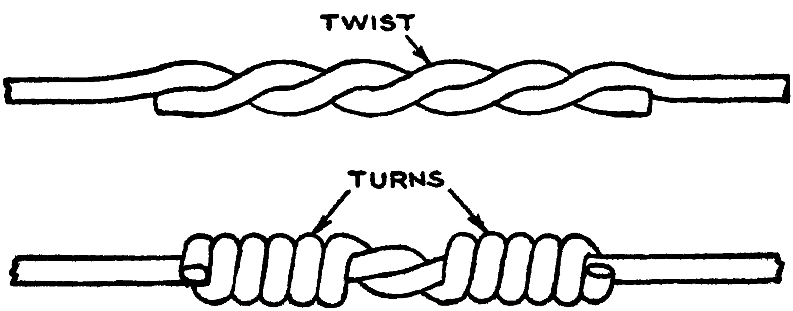
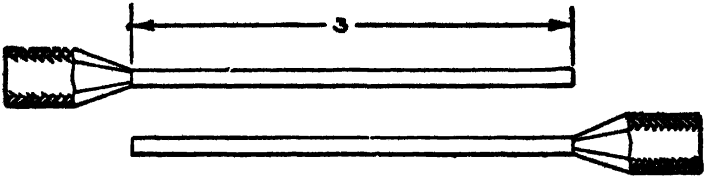


FIG. 5,121.—Method of using Austin cable ripper. *In operation,* squeeze and pull. This the cutter to sink into the outer braid and rip same.



FIGS. 5,122 and 5,123.—Twists and turns. In making twists each wire is wrapped around the other, whereas in making turns one wire remains straight, the other wire being wrapped around the straight wire.



FIGS. 5,124 and 5,125.—*Bell hanger's joint 1.* Strip off 3 ins. of insulation from end of each wire and clean.

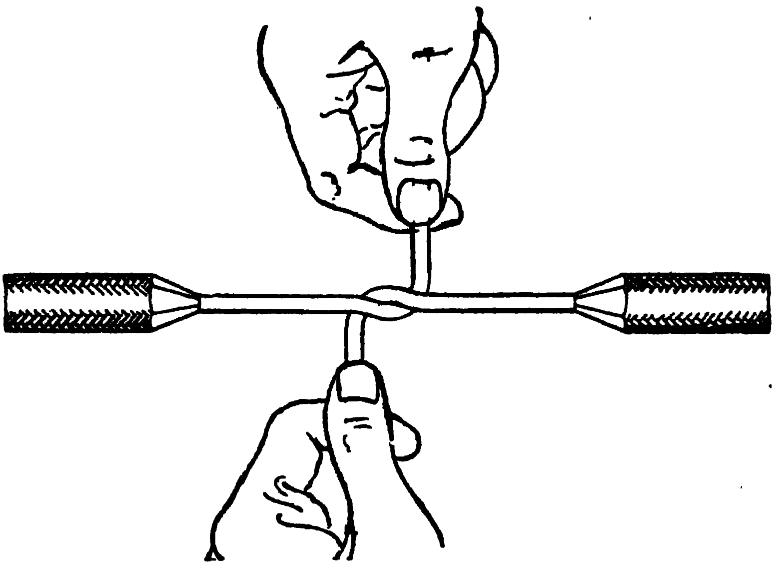
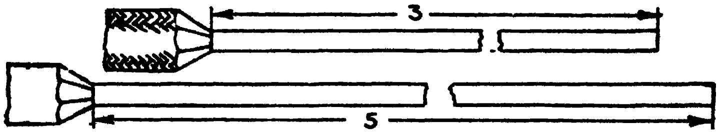


FIG. 5,126.—*Bell hanger's joint 2.* Bring wires together and make one turn as shown, then hold first wire with hand and twist second wire with pliers. Similarly twist first wire. The twisting may be done by hand for small wire, but for large wire, pliers are necessary.

FIG. 5,127.—*Bell hanger's joint 3.* Appearance of completed joint before soldering and tap(e)ing.

contact between the ends of the wires and so that the solder will adhere properly. The wires may be cleaned by scraping.

If this be done with a knife, care should be taken to avoid nicking the wire. Sand paper may be used to clean the wires.



FIGS. 5,128 and 5,129 —*Turn back joint 1.* Strip off 3 ins. of insulation from one wire and 5 ins. from the other and clean the exposed ends.

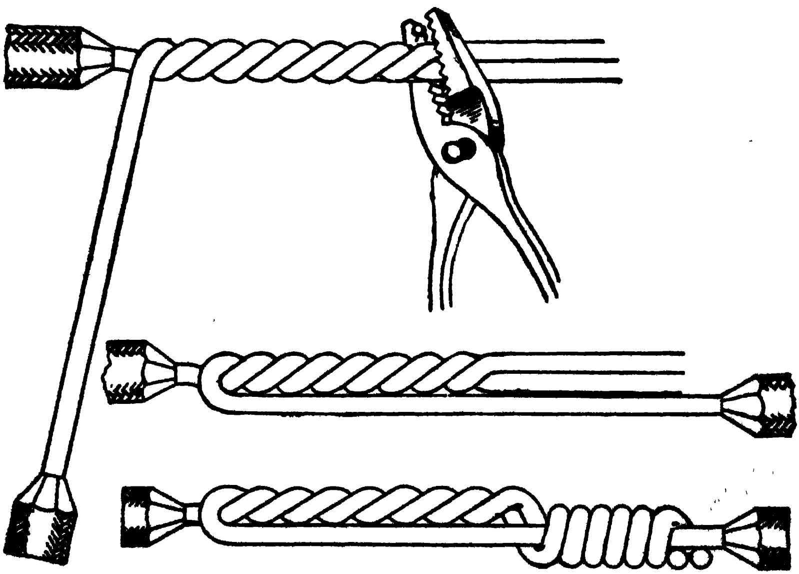


FIG. 5,130.—*Turn back joint 2.* With the ends of the wires together twist the wires, using pliers and leaving about one inch straight at the end.

FIG. 5,131.—*Turn back joint 3.* Turn back the long wire until it becomes parallel with the

FIG. 5,132.—*Turn back joint 4.* Turn the two straight ends around the long wire between the twisted portion and the insulation, thus completing the joint. There should be e straight wire left after twisting to make several turns.

Joints.—There is a multiplicity of joints designed to meet the requirements of different kinds of wiring. The duty to be performed by a joint determines the kind to be used.

In some cases all that is required is that the joint be electrically good as for instance the pig tail splice used in junction or fixture outlet boxes; in other cases, the joint must be both electrically and mechanically good, as for instance, joints on an overhead line must be made so that they will withstand considerable tensile stress due to weight of the suspended conductor

There are a number of joints extensively used of which the following should be noted:

Fig. 5,133.—Western Union joint complete.

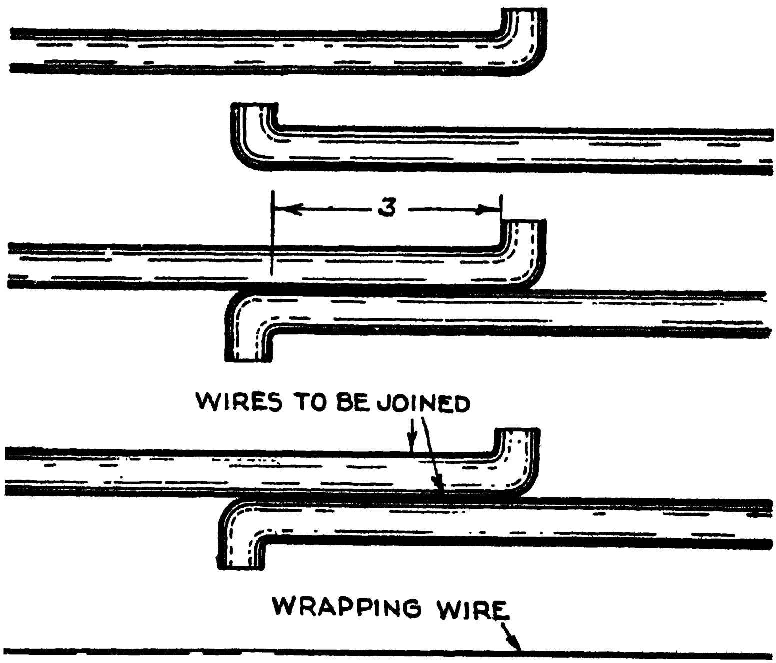
1. Pig tail;
2. Bell hanger's;
3. Western Union;
4. Turn back;
5. Britannia;
6. Scarfed;
7. Duplex.

The pig tail joint as before mentioned is suitable for service where there is no mechanical stress as where wires are to be connected in an outlet box, switch or conduit fitting. Figs. 5,118 and 5,119 show the method of making this joint.

The bell hanger's joint was, as its name implies, originally intended for bell circuits, however on account of its being not only electrically and mechanically strong, but also compact, it has numerous other uses where the tensile stress is not too great.

The joint consists of one twist and no less than five turns of each wire about the others. The difference between twists and turns is shown in figs. 5,122 and 5,123 and the method of making a bell hanger's joint in figs. 5,124 to 5,127.

The Western Union joint is a modified form of the bell hanger's joint. It is made in the same way as the bell hanger's joint with the exception that



FIGS. 5,134 and 5,135.—*Britannia joint 1.* Bend up at right angles the end of each wire. Use a hand vise and hammer as a sharp bend cannot be made with pliers.

FIG. 5,136.—*Brittania joint 2.* Place the wires together so that they overlap about 3 ins.

FIGS. 5,137 and 5,138.—*Britannia joint 3.* Assuming the wires to be joined are No. 6, use a No. 18 wrapping wire. Take about 6 ft. of the wrapping wire, clean it and bend in half.

a number of twists are taken instead of one. The object of the extra twists is to make it more efficient mechanically as the tensile stress brought on these joints is considerable. Fig. 5,133 shows appearance of the completed joint.

The turn back joint is useful in connecting two wires that must be drawn taut.

The Britannia joint is sometimes used on overhead lines where considerable tensile strength is required. It is also used both for inside and outside wiring where single conductors of sizes No. 6 or larger are used. Figs. 5,134 to 5,141 show how the joint is made.

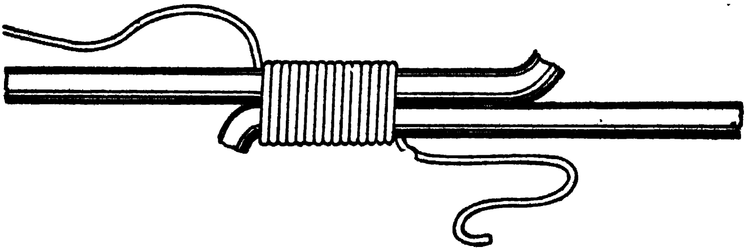


FIG. 5,139.—*Britannia joint 4.* Place the center of the wrapping wire at the center of the joint and wrap each half toward the ends of the joint.

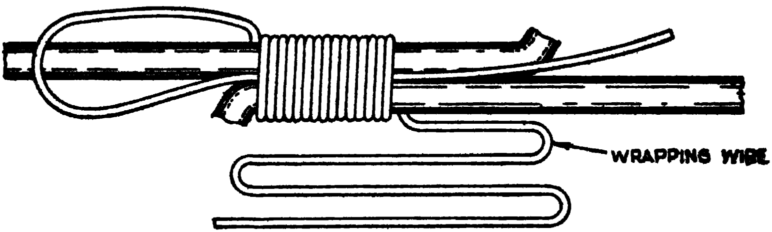


FIG. 5,140.—*Britannia joint 5.* After wrapping, force the free ends of the wrapping wire through the grooves formed by the wrap and large wires. Illustration shows one end being pulled through.

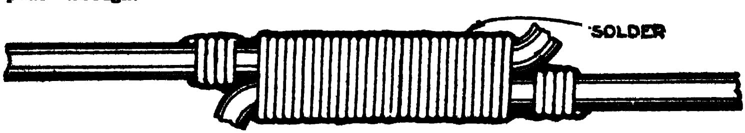
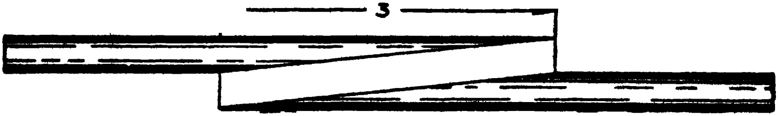


FIG. 5,141.—*Britannia joint 6.* With the portion of wrapping wire remaining after pulling through, make a few turns around the large wires at each end of the joint.

A scarfed joint is used on large wires where appearance and compactness are the main considerations and where the joint is not subject to any heavy tensile stress. The method of making the joint is shown in figs. 5,142 to 5,144.

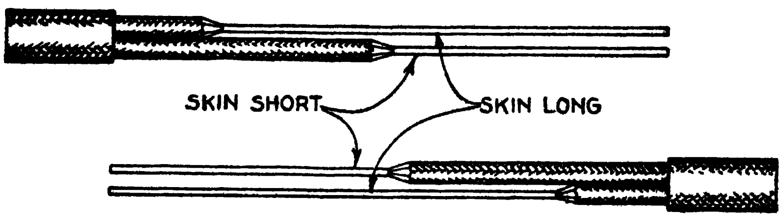
A duplex joint is used in conduit systems where twin wires are used, that

is, two wire cables. It will be seen from the illustration that the joint consists of two bell hanger's joints spaced so that they do not come opposite each other. See figs. 5,145 to 5,148.

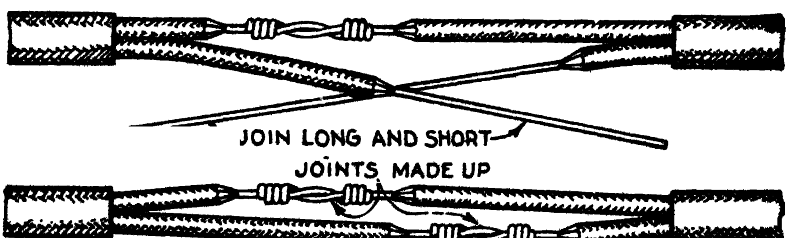


FIGS. 5,142 and 5,143.—*Scarf joint 1.* The ends of the two wires to be joined are scarfed as here shown, that is, filed wedge shaped. The scarf should be about 3 ins. long bringing the ends to a fine point making a good fit. When filing, the ends of the conductors are most conveniently held by laying them in a groove in a block of wood. The wires when fitted together should appear like one continuous wire.

FIG. 5,144.—*Scarf joint 2.* Tin the ends, then wrap with No. 18 or No. 20 wire, starting at the middle of the joint and wrapping toward the ends similarly as with the Britannia joint, except that the ends instead of being pulled through are wrapped a few turns beyond the ends of the joint. Solder the joint.



FIGS. 5,145 and 5,146.—*Duplex joint 1.* Skin or remove about 3 ins. of the outer braid from each cable and remove insulation from each wire as shown, that is, so the joints will not come opposite each other.



FIGS. 5,147 and 5,148.—*Duplex joint 2.* Make up joints. Fig. 5,147 shows one joint made and fig. 5,148 both joints complete. Note that these joints do not come opposite each other, thus giving better insulation.

Taps.—By definition, a tap is *the connection of the end of one wire to some point along the run of another wire.*

As with joints, there are various taps to meet different conditions. The following should be noted.

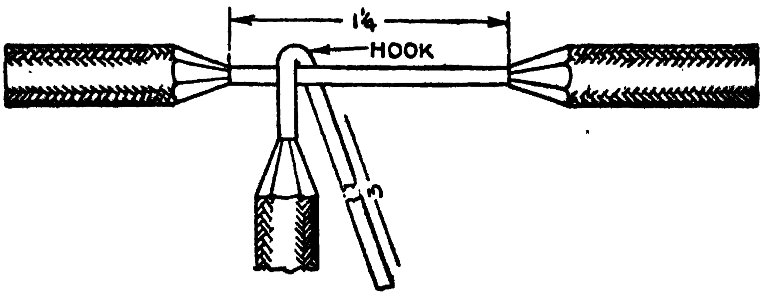


FIG. 5,149.—*Plain tap 1.* Remove about 1¼ in. of insulation along the run wire and about 3 ins. at the end of the tap wire. Cross the wires about ¼ in. from insulation and take a *hook.*

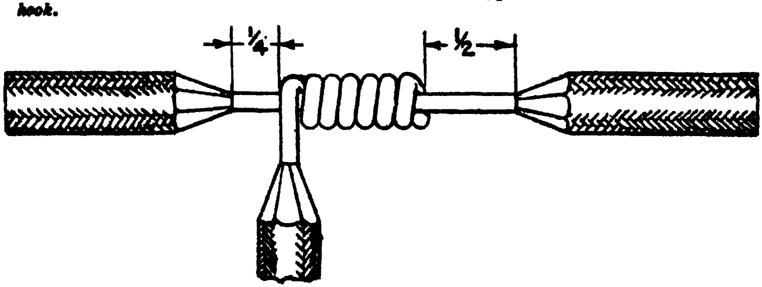


FIG. 5,150.—*Plain tap 2.* Take 5 or 6 turns of the tap wire around the run wire. Note that the joint should terminate about ½ in. from the insulation on the run wire. This permits soldering without burning the insulation and gives better chance for tap(e)ing.

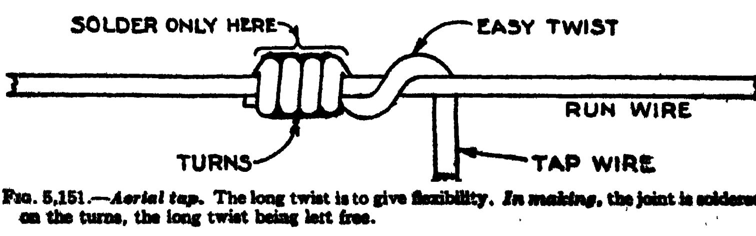
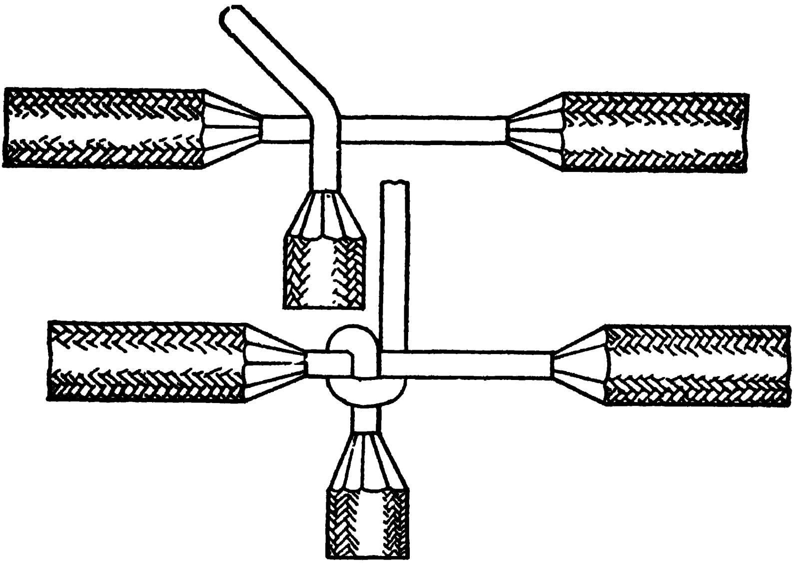


FIG. 5,151.—*Aerial tap.* The long twist is to give flexibility. *In making,* the joint is soldered on the turns, the long twist being left free.

1. Plain;
2. Aerial;
3. Knotted;



FIGS. 5,152 and 5,153.—*Knotted tap 1.* Remove 1½ to 2 ins. of insulation from run wire and 3 ins. from tap wire. Make knot as shown in fig. 5,153 and note carefully how it is made.

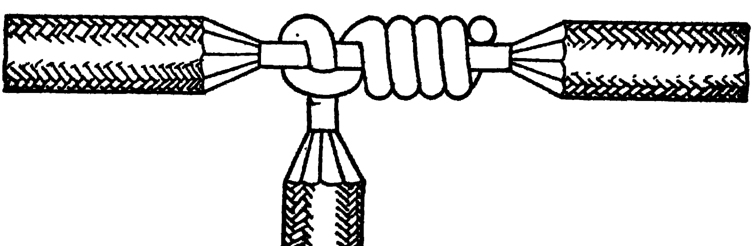


FIG. 5,154.—*Knotted tap 2.* Make several turns.

4. Cross;
   a. Double;
   b. Duplex;
5. Wrapped.

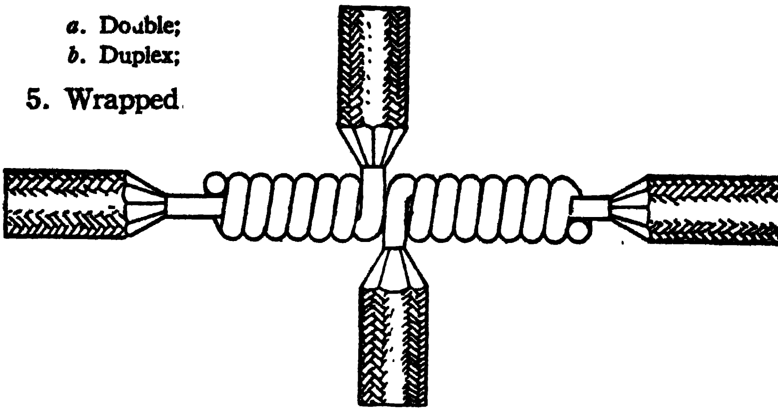


FIG. 5,155.—***Double cross tap.*** For this tap remove about 2½ ins. of insulation from the run wire and about ¼ in. from each tap wire. Each tap is made as described for the plain taps; the taps starting at the middle of the joint and running in opposite directions.

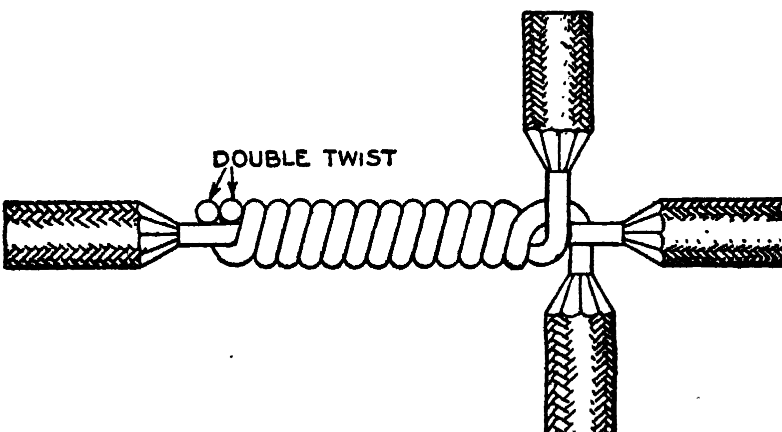
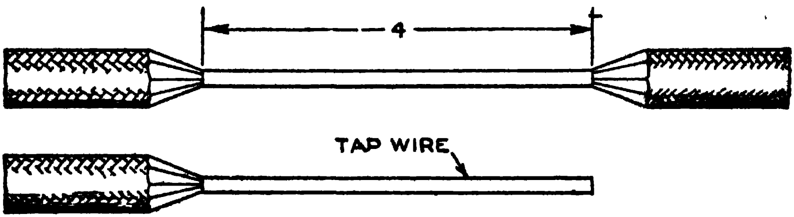


FIG. 5,156.—***Duplex cross tap.***—Remove about 2 ins. of insulation from the run wire and about 3 ins. from each tap wire. Bring the two tap wires across the run wire at one end of the joint and double twist the ends of the tap wires.

The plain tap is the one most frequently used and is quickly made without difficulty as is seen in figs. 5,149 and 5,150.

The aerial tap is intended for wires subjected to considerable movement. It is similar to the plain tap except that it has a long or easy twist as in fig. 5,151 to permit of movement.



FIGS. 5,157 and 5,158.—*Wrapped tap 1.* Using a No. 6 wire remove about 4 ins. of insulation from both wires.

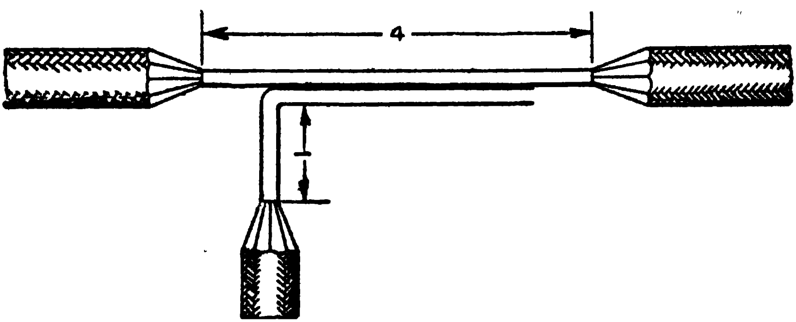


FIG. 5,159.—*Wrapped tap 2.* Bend the tap wire in the shape of an L with bend about 1 in. from insulation and place it along the run wire as shown.

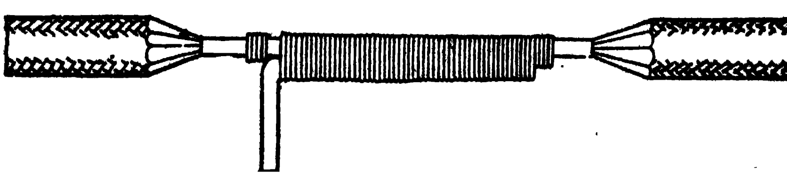


FIG. 5,160.—*Wrapped Tap 3.* Wrap in a similar manner as described for the Britannia joint figs 5,139 to 5,141.

A knotted tap, as must be evident, is designed to take considerable tensile stress and is made as shown in figs. 5,152 to 5,154.

A double cross tap is simply a combination of two plain taps as shown in fig. 5,155.

The duplex cross tap is used where two wires are to be tapped at the same time, because it can be made quicker. Fig. 5,156 shows its features.

A wrapped tap is used on wires too large to wrap around the run wire. The joint is made as shown in figs. 5,157 to 5,160.

TEST QUESTIONS

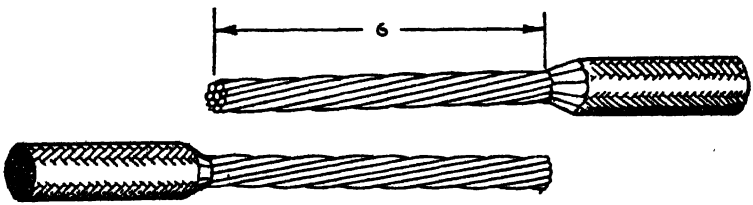
1. *What is the difference between a joint and a tap?*
2. *Name five operations to be performed in making a joint or tap.*
3. *What names are sometimes given to the operation of removing the insulation from the wire?*
4. *What is the usual though wrong way of removing insulation?*
5. *What should be done after removing the insulation?*
6. *What is the difference between a turn and a twist?*
7. *Describe the bell hanger's joint.*
8. *Describe the turn back joint.*
9. *For what is the pig tail joint suitable?*
10. *For what is a Britannia joint sometimes used?*
11. *What is a scarf joint?*
12. *Describe the operation of making a duplex cross tap*
13. *Describe how the various taps are made.*
14. *What kind of tap is most frequently used?*

15. *For what is the aerial tap intended?*
16. *For what service is the knotted tap intended?*
17. *When is the duplex cross tap used?*
18. *What is the feature of the wrapped tap?*

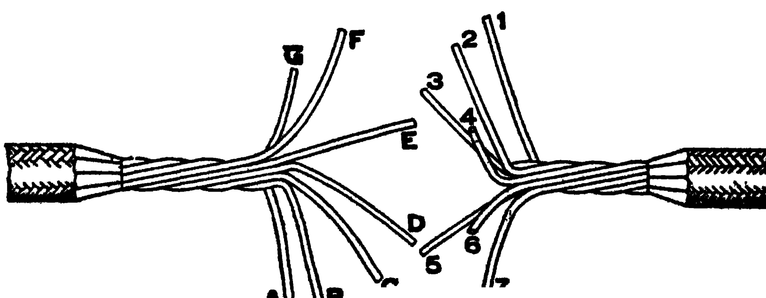
CHAPTER 101

Splices

As pointed out in the preceding chapter there is considerable difference between a *joint* and a *splice* yet the word *splice* is



FIGS. 5,161 and 5,162.—*Single wrapped splice 1.* Remove about 6 ins. of insulation from each cable and clean each strand.



FIGS. 5,163 and 5,164.—*Single wrapped splice 2.* Lay up (that is, wrap) the strands for a distance of about 2 ins. from the end of the insulation of each cable and *fan out* the strands to an angle of about 30°.

commonly though incorrectly used for *joint*. The latter term relates to single wire conductors and splice to multi-wire or stranded conductors.*

For this reason the author excludes splicing from the chapter on joints and taps as it is a different subject.

Running Butt Splice.—The term *running butt* relates to splices formed by butting together the ends of two cable lengths

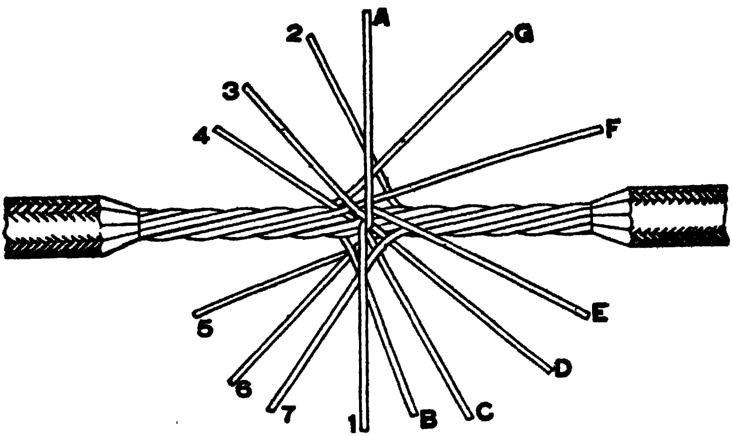


FIG. 5,165.—*Single wrapped splice 3.* Interweave the strands by bringing together the laid up sections, and in so doing see that one strand only of each wire passes between two strands of the other in each case. Make a *hook* by sharply bending say strands 1 and A.

to extend the run or length of circuit as distinguished from tap splices later described.

According to the method of wrapping the strands, running butt splices are classified as:

*NOTE.—*According to the dictionary,* the word splice is defined as *to unite (two ropes or parts of a rope) as by interweaving or intertwining the strands.* Since single wire conductors are not made up of strands the word splice does not apply to them.

1. Single wrapped;
2. Multiple wrapped.

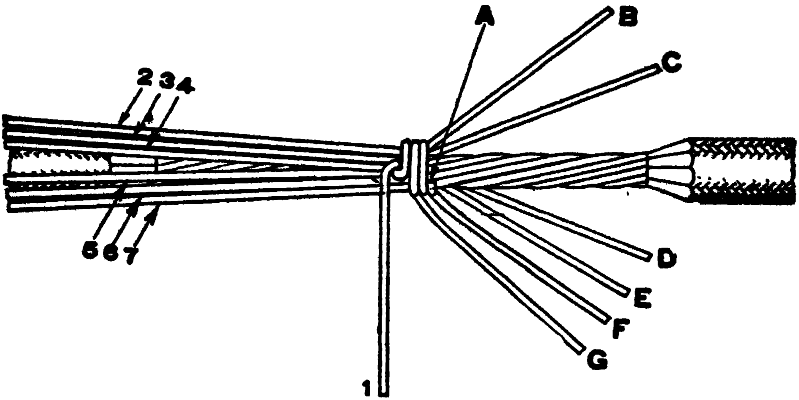


FIG. 5,166.—*Single wrapped splice 4.* Wrap tightly one strand as strand 1 around the laid up portion of the cable.

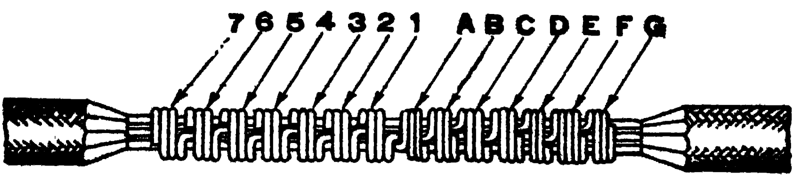
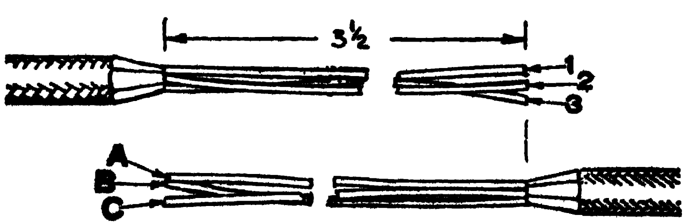


FIG. 5,167.—*Single wrapped splice 5.* Similarly as in fig. 5,166, wrap tightly each of the remaining strands of each cable around the laid up portion of the other cable.



FIGS. 5,168 and 5,169.—*Multiple wrapped splice 1.* Remove about 3½ ins. of insulation from each cable and clean each strand.

Single Wrapped Splice.—This kind of splice is used for large wires (No. 6 or larger) because it is easier to wrap a single wire at a turn than to wrap them all at once.

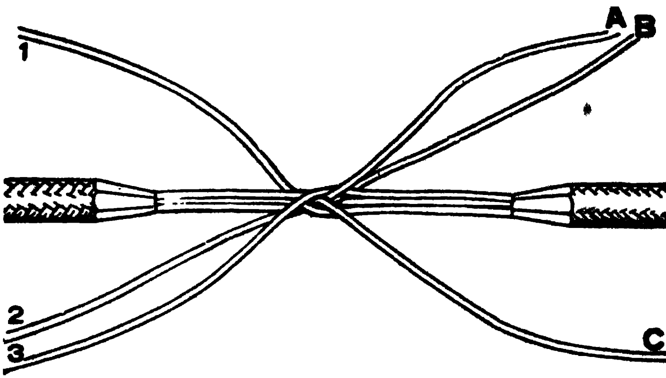


FIG. 5,170.—*Multiple wrapped splice 2.* Lay up the strands for a distance of 1 in. from the insulation. Fan the free ends and butt together properly intertwining the strands.

FIG 5,171.—*Multiple wrapped splice 3.* Wrap tightly the strands of one cable around the laid up portion of the other cable. Similarly wrap the strands of the other cable.

For a No. 4 or No. 6 wire the insulation is removed from the ends of the cable a distance of about 6 inches, larger sizes in proportion. The method of making a single wrapped splice is illustrated in figs. 5,161 to 5,167.

Multiple Wrapped Splices.—This method of wrapping is generally used on small cables because the strands are flexible and all can be wrapped in one operation. A three strand cable is selected so as to clearly show the method of wrapping.

In this splice all strands in each group are wrapped simultaneously and parallel with each other. Figs. 5,168 to 5,171 show the various operations. The strands are No. 20 wire and are exaggerated in size in the illustrations for clearness.

Tap Splices.—These are made when the end of one stranded conductor is to be connected at some point along the run of another stranded conductor.

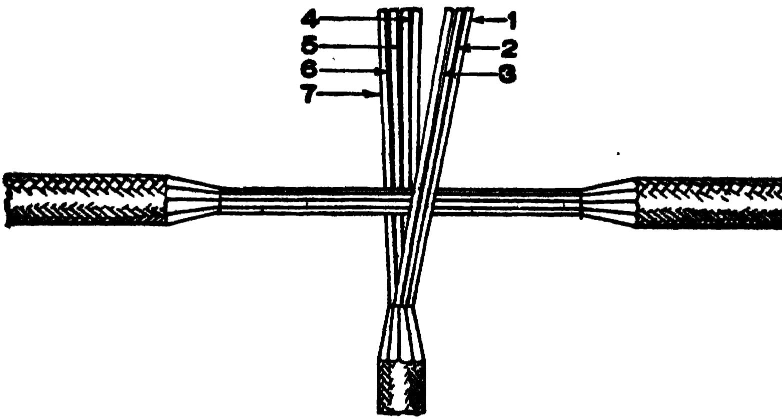


FIG. 5,172.—*Ordinary tap splice 1.* Remove insulation to a distance depending upon the size of the wires. Place tap conductor at center of splice and divide up the strands as shown.

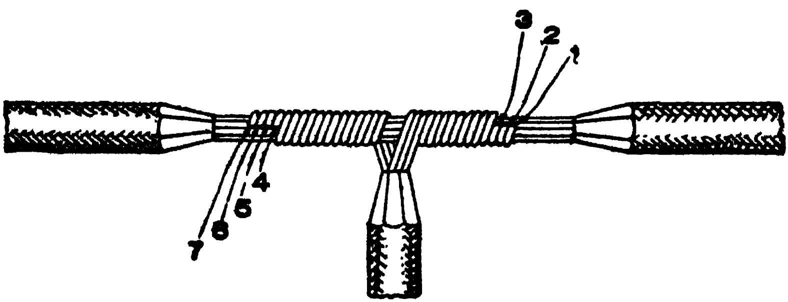


FIG. 5,173.—*Ordinary tap splice 2.* Wrap tightly strands in multiple as shown for small wires.

They may be classed as:

1. Ordinary;

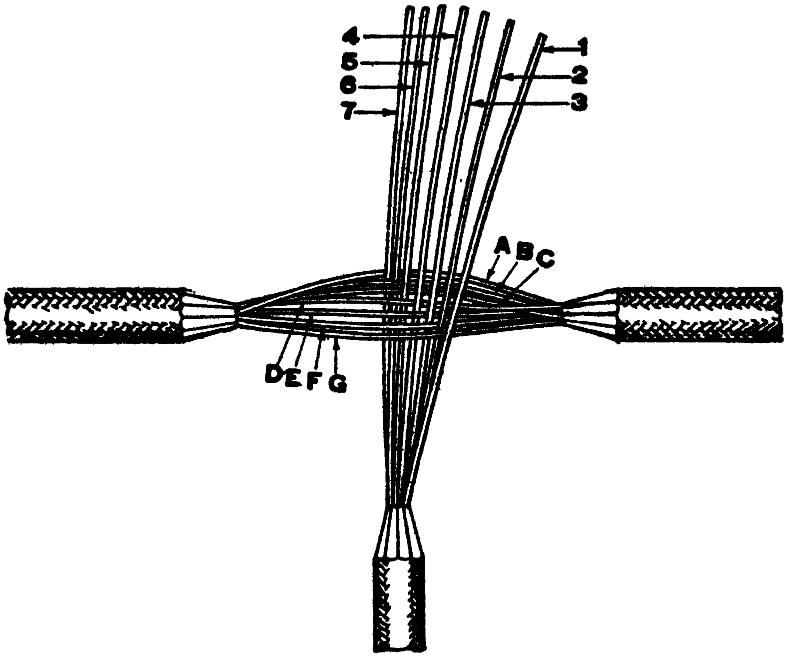


FIG. 5,174.—*Split tap splice 1.* Remove insulation to a distance depending upon the size of the wires. Place tap conductor at center of splice and interweave the strands as shown.

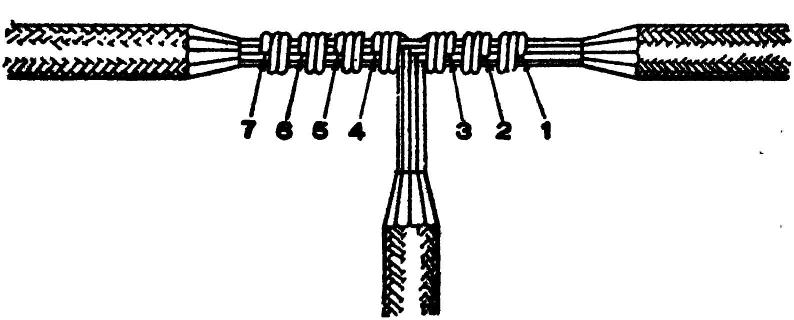


FIG. 5,175.—*Split tap splice 2.* Wrap the strands on each side toward end of splice. The [illegible] wrapped tap splice.

2. Split;
3. Y splice.

In the method of wrapping they may be either singly wrapped, or multiple wrapped, the choice depending on the size of the strands. The accompanying illustrations show the various tap splices.

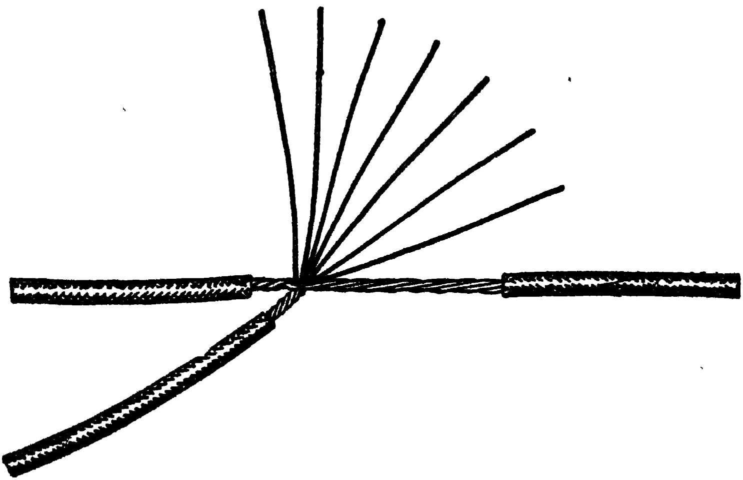


FIG. 5,176.—*Y splice 1.* Remove insulation to a distance depending upon the size of wire. Interweave the tap wire strands through the run wire strands at one end of the splice and twist up the run wire strands in the original direction.

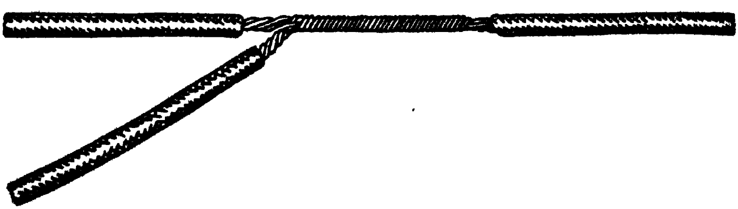


FIG. 5,177.—*Y splice 2.* Tightly wrap the strands of the tap wire around the run either by the single or multiple method, depending upon the size of the wires.

TEST QUESTIONS

1. *What is the difference between a splice and a joint, or a tap?*
2. *What is a running butt splice?*
3. *Name two kinds of running butt splice.*
4. *Describe how to make the single wrapped splice and a multiple wrapped splice.*
5. *Describe how to make:* 1, *ordinary tap splice;* 2, *split tap splice.*

CHAPTER 102

Soldering and Tap(e)ing

By definition, soldering is the act or process of forming joints upon or between metallic surfaces, by means of a fusible alloy or solder, whose melting point is lower than that of the metals to be united.

Solder.—The word solder is a name for *any fusible alloy used to unite* different metal parts.

In electrical engineering the solder used is practically always an alloy of tin and lead. As the electrical conductivity of such an alloy is usually about one-seventh that of copper, the best joint between copper conductors is made *by bringing the copper surfaces as close together as possible and using a minimum of solder.*

Soldering.—Briefly the theory of soldering is that: *as the solder adheres to and unites with the surface of the copper when the bit is tinned, so will it adhere to and unite the surfaces of the metals to be soldered.*

The operations to be performed in soldering are:

1. Cleaning the surface to be soldered;
2. Heating the bit;
3. "Tinning" the bit;
4. Applying the flux;

5. Picking up solder;
6. Applying the bit.

These six operations constitute, in general, soldering. They are performed in various ways depending upon the nature of the work.

The essential conditions for successful soldering are:

1. Clean surfaces;
2. Correct temperature of bit;
3. Careful fluxing and tinning.

When these conditions are given proper attention the art of soldering without profanity, presents no difficulties.

Methods of Soldering.—There are several ways of performing the essential operations of soldering and as previously mentioned the choice depends upon the nature of the work. The methods mostly used are:

1. Soldering with bit;
2. Soldering with gasoline blow torch;
3. Soldering with alcohol blow torch;
4. Sweating.

all of which are later described in detail.

Soldering Fluxes.—The word *flux*, means a *substance applied to a metal to make solder flow readily on its surface.*

The action of a flux is largely that of cleaning the surface, and of reducing any oxide on the surface to the metallic state.

If a piece of sheet copper be carefully cleaned by means of emery cloth and heated over a gas flame, the surface will be seen to tarnish rapidly and assume a dark brown appearance. A small piece of resin dropped on the surface will melt, and when the liquid runs, the initial brightness of the surface will be found to reappear.

There are a number of fluxes suitable for various kinds of soldering, but pine amber resin is the best for electrical work as it does not cause corrosion. A corrosive flux, such as zinc chloride solution (killed spirits) should be strictly excluded from any electrical work. The nature of the solder often determines the flux. For soldering copper and brass, use sal-ammoniac as flux.

Soldering Bolts or Bits.—The erroneously called soldering "iron" or bit consists of a large piece of copper, drawn to a

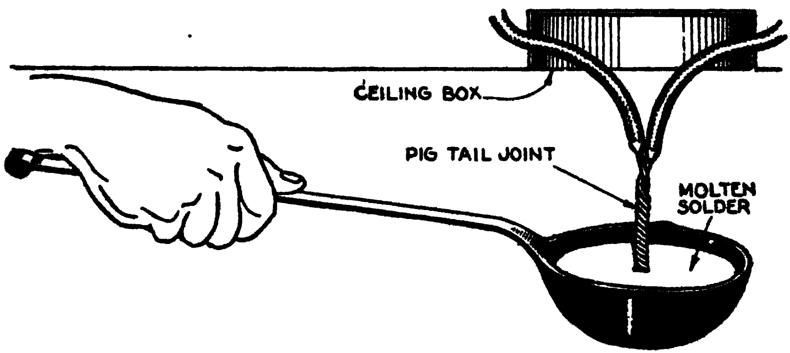


FIG. 5,178.—Use of soldering ladle in soldering an overhead pig tail joint as from a ceiling box. *At the first dipping*, perhaps too much solder will adhere to the joint and if so this may be corrected by subsequent dipping which heats up the twisted wires so that the excess solder will fall back into the ladle.

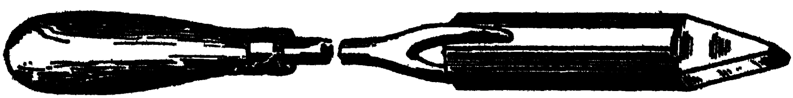


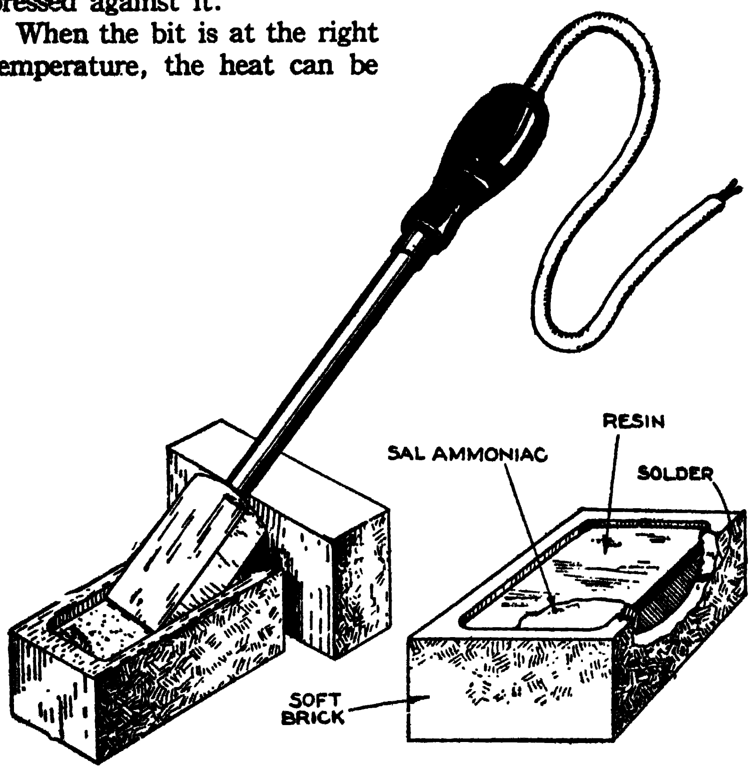
FIG. 5,179.—Ordinary soldering bit, incorrectly called *soldering iron*.

point or edge and fastened to an iron rod having a wooden handle, as shown in fig. 5.179.

Tinning the Bit.—Preliminary to soldering, ***the bit must be coated with solder***, this operation being known as "tinning."

To tin a soldering bit, heat it in a fire or gas flame until hot enough to melt a stick of solder rapidly when it is lightly pressed against it.

When the bit is at the right temperature, the heat can be

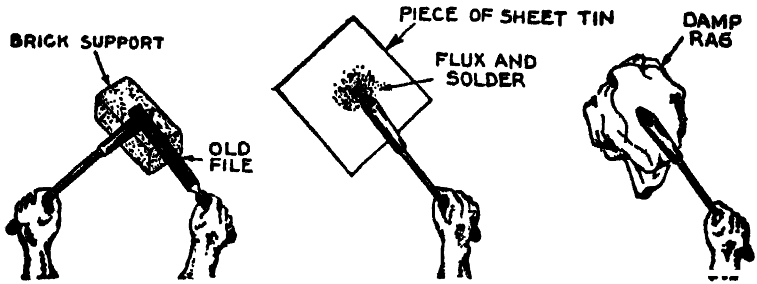


FIGS. 5,180 and 5,181.—Tinning block for electric soldering tool. It is made with two soft bricks. One brick is used to support the soldering tool, and the other to contain the tinning material and to furnish a material which will keep the copper bit bright enough to receive its coating of "tin." Fig. 5,181 shows part of the tinning brick in section, which is scooped out on top as shown by the lower line. Into one end of the hollow in the brick, some sal-ammoniac is placed to help tin the copper bit. Sal-ammoniac is a natural flux for copper and aids greatly in keeping the tool well tinned. Some melted solder is run into the hollow of the brick, and enough resin to fill the cavity nearly to the top.

felt when it is held close to the face, as in fig. 5,186. When hot enough clean up the surface of the copper with an old file, or scrape it on a brick.

If the temperature be too high, the copper surface will be found to tarnish immediately, in which case the soldering bit must be allowed to cool slightly and the cleaning repeated.

When the surface only tarnishes slowly, it is at the right temperature for tinning. Take a piece of *tin plate* (ignorantly called *sheet tin* or just "tin") and place on it some solder and flux, and rub the bit on same. The process of tinning is shown in figs. 5,182 to 5,184.



FIGS. 5,182 to 5,184.—"Tinning" the bit. Fig. 5,182, cleaning bit by filing working surfaces with an old file; fig. 5,183, rubbing the bit on the flux and solder, which may be conveniently placed on a piece of sheet tin as shown; fig. 5,184, removing surplus solder by giving each side of the bit a quick stroke over a damp rag.

After the molten metal has spread over the whole of the surface which it is desired to tin, the superfluous solder is wiped off with a clean damp rag.

The surface should present a bright silvery appearance when properly tinned.

Once a soldering bit has been well tinned care should be taken not to overheat it. If the bit at any time reach a red heat it will be necessary to repeat the whole tinning process before it is fit to be used again. No good work *can be done with an untinned or badly tinned bit.*

If the bit be forgotten and left in the fire, heat to redness and then plunge into cold water, when most of the hard oxidised surface will scale off. A soft coal fire will quickly destroy the tinning.

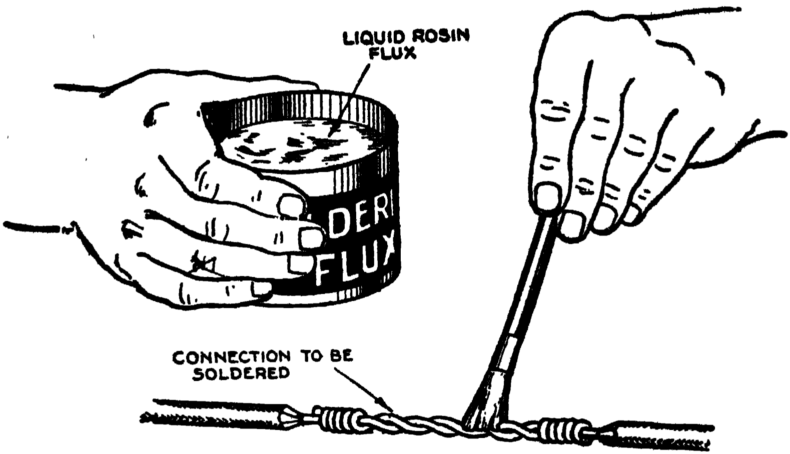


FIG. 5,185.—Method of applying liquid rosin flux with brush to wire connection to be soldered.

FIG. 5,186.—Method of judging the heat of a soldering bit by holding it near the face

Applying the Flux.—Resin which is recommended as a flux comes in lumps, but it can be granulated by grinding it in a coffee grinder or by hammering.

The resin may be sprinkled over the surface to be soldered or may be applied in liquid form by dissolving in alcohol. In the liquid form it may be applied with a brush as in fig. 5,185. Resin is sometimes called *rosin*.

Applying the Solder.—The method used in applying the solder to the parts to be soldered depends upon the nature of the work. It may be applied by:

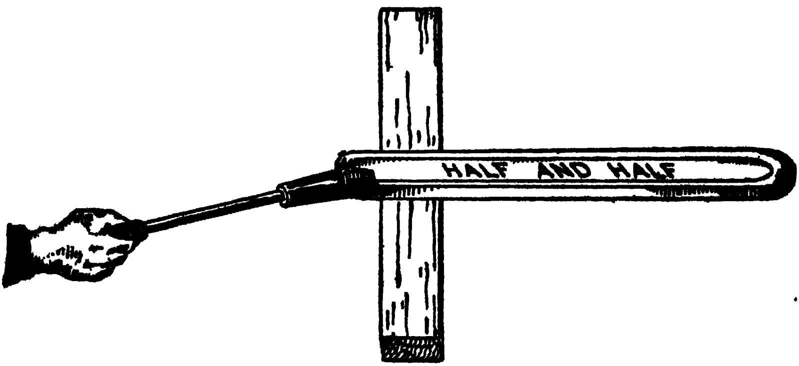
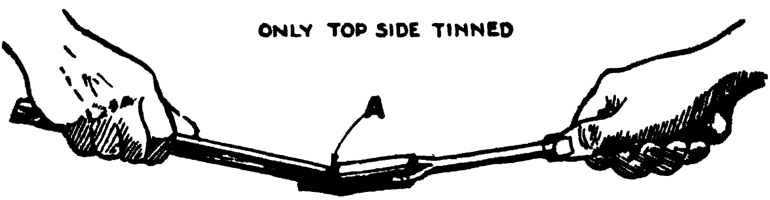


FIG. 5,187.—Picking up solder with a hot bit. This is the proper method for small work. Rest the bar of solder on some support as a brick or piece of wood and touch it with the end of the hot bit. Some of the solder will melt and remain on the bit. *In picking up solder* from the stick, care should be taken not to leave the bit in contact with the solder too long or some of it will drop off. The larger the bit and area tinned, the more solder will the bit hold.

NOTE.—*On electrical work* the Underwriters' Code permits the use of a flux composed of chloride of zinc, alcohol, glycerine and water. This preparation is easily applied and remains in place. It permits the solder to flow freely and is not highly corrosive. This flux is made as follows: Zinc chloride, 5 parts; alcohol, 4 parts; glycerine, 3 parts. Anhydrous zinc chloride crystals should be used dissolved in alcohol. The glycerine makes the flux adhesive. To prevent the alcohol igniting, the mixture may be diluted with water. There are a number of prepared fluxes on the market, but are not to be recommended because of the ridiculously high prices demanded. *For electrical work, especially when very small wires are used, rosin should be insisted upon to avoid any corrosion.* No one flux can be assigned to any one metal as being peculiarly adapted or fitted to that metal for all purposes. The nature of the solder often determines the flux.

1. Picking up;
2. Melting on the work.

For soldering small wires, the first method is used. The solder is *picked up* as in fig. 5,187, and then applied to the joint, as in fig. 5,189. Since *heat rises*, the bit is more efficiently applied underneath the parts to be soldered. The difficulty encountered with such application is to retain



Figs. 5,188 and 5,189.—Soldering small wire connections by the picking up method. Tin one side only of the bit. If the bit be already tinned on all four faces file bit clear down to copper on all but one side and apply solder as in fig. 5,188. The bit is now ready and may be used without the annoyance of the solder leaving the working face or dropping on the floor below.

the solder at the right place on the bit. This is accomplished by tinning only one face of the bit as **A** in fig. 5,188, which will cause the melted solder to remain on the upper or tinned face, so that the soldering is easily done as in fig. 5,189.

The second method of melting the solder on the work is a

top method, that is the *stick* of solder is held on top of the work.

The bit is more efficiently applied from below as before stated, as it allows the heat to rise melting the solder and allowing it to flow into the

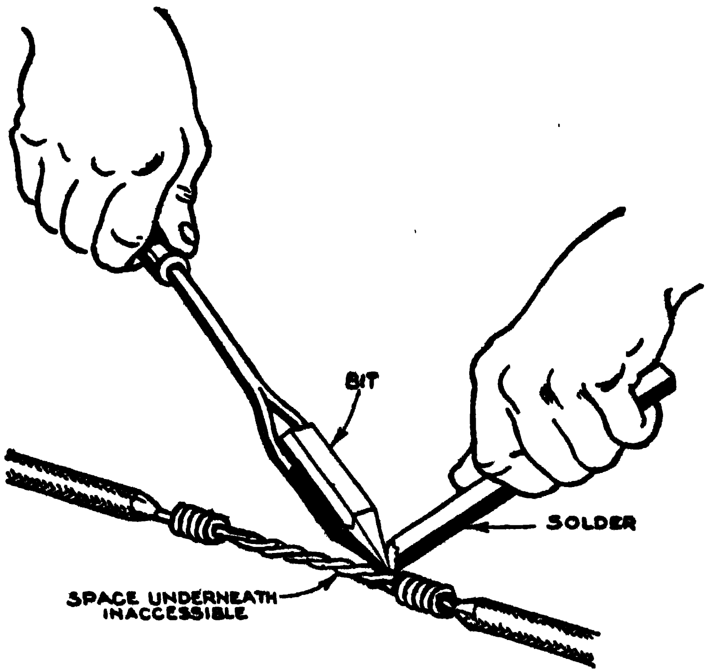


FIG. 5,190.—Method of soldering by melting the solder on the work. This is naturally a *top* method and requires a hotter bit than the picking up method shown in figs. 5,188 and 5,189.

crevices. When it is found impossible to apply the heat from below, the soldering copper may be placed at the top, as in fig. 5,190, in which case it will be found necessary to increase the heat of the copper.

Soldering with a Gasoline Blow Torch.—Instead of applying the heat for soldering with a bit, it is sometimes more

conveniently done by applying the flame of a blow torch direct to the work.

The operation of a blow torch is explained in fig. 5,192, and of a gasoline

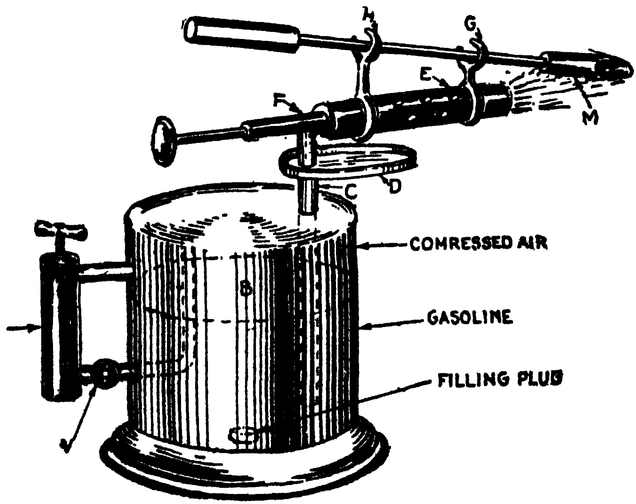


FIG. 5,191.—Gasoline torch with rests for holding soldering bit. *In construction* A, is a hand air pump, which may have automatic, or hand operated valve; B, is the reservoir containing gasoline and compressed air, the latter being furnished by the pump. A valve V, prevents leakage of the compressed air through pump. A pipe C, projects to bottom of reservoir, as indicated by dotted lines, and connects with vaporizer E, through needle valve F. A trough D, is for holding a small quantity of gasoline to heat vaporizer E, in starting. Two supports H and G, clamped to the vaposizer support a soldering bit so that it will rest in the flame in heating. *In operation*, the reservoir is filled about two-thirds full through filler plug and the pump given a few strokes to compress air in the top of reservoir. After heating vaporizer F, with a little gasoline placed in D, needle valve F, is opened slightly. The gasoline under pressure on the reservoir will flow through needle valve F, into the vaporizer and ignite. As the vapor becomes hotter the valve may be given more opening and when fully heated an almost colorless flame of great heat will issue from the end of the vaporizer. Air supply is admitted into the vaporizer through the small holes shown. In attaching the supports H, G, care should be taken not to cover any of the air holes, because this will cause a poor flame.

torch in fig. 5,191. After fluxing, the joint or splice is heated above the melting point of solder. The latter is applied from the top so that it will flow all over the wires and into the crevices.

For small wire connections a mouth or *pin flame* alcohol blow torch should be used as shown in fig. 5,192.

Sweating.—In this operation the surfaces to be joined are cleaned, heated, fluxed and covered with a film of solder. The soldered surfaces are then placed together and heated either

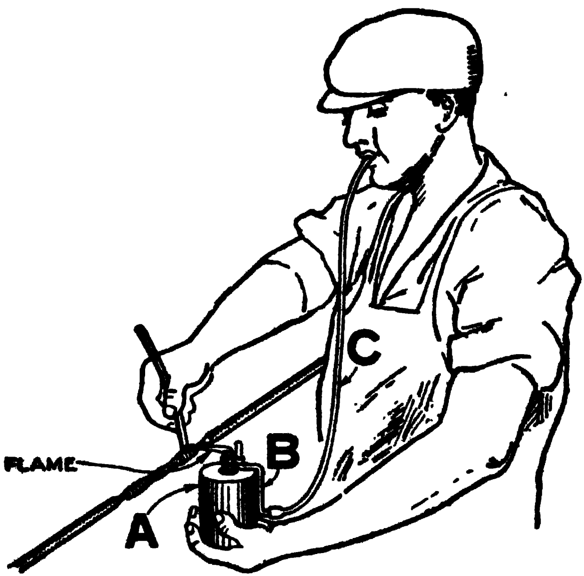
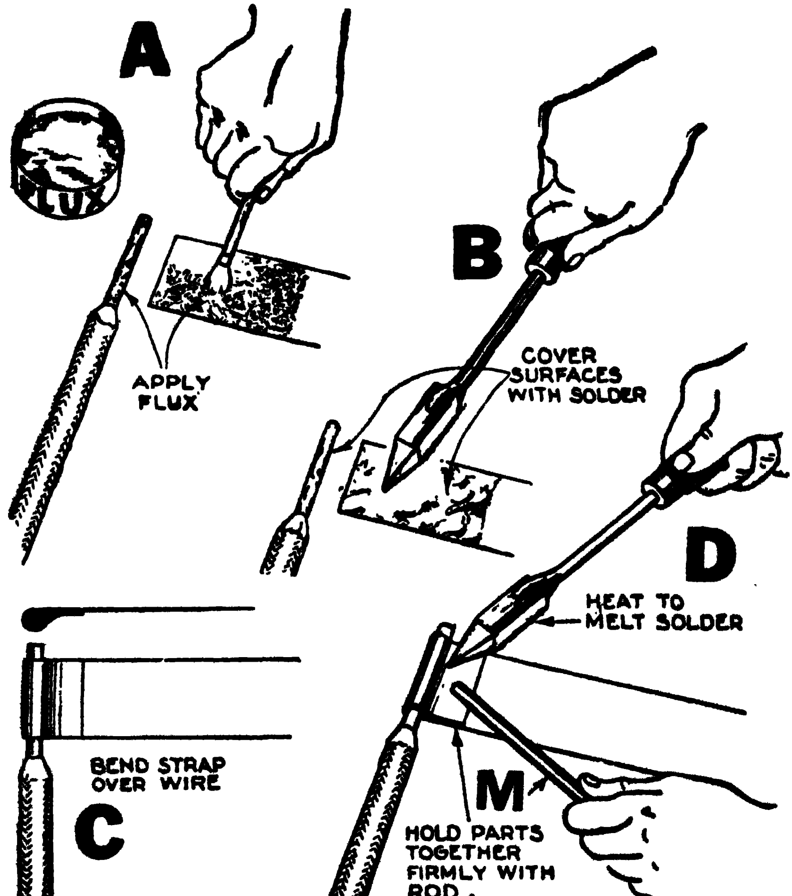


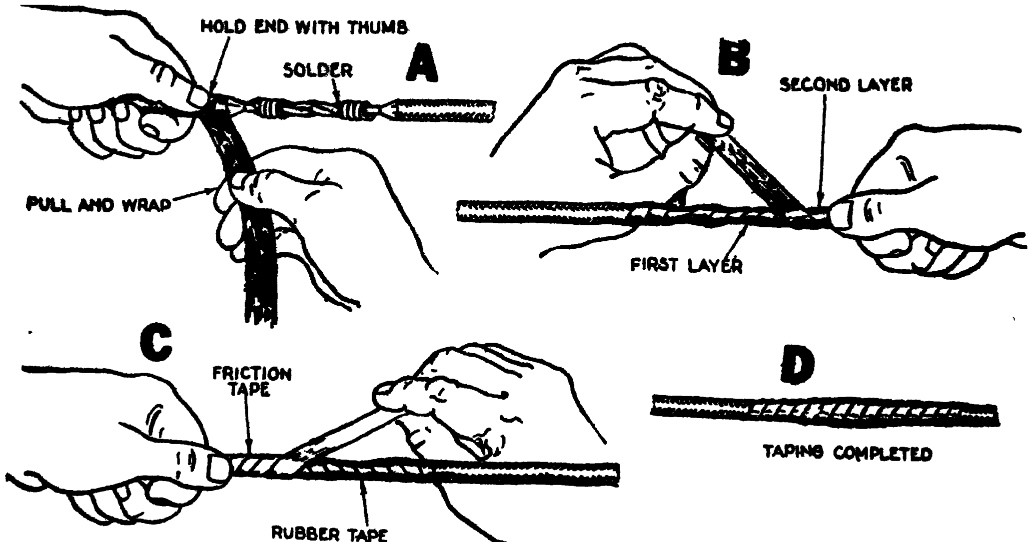
FIG. 5,192.—Pin flame alcohol blow torch. *It consists* of an ordinary wick torch A, provided with a blow pipe B, having a rubber tube extension, C, for blowing. *In operation*, the blowing pressure should be regulated so that the flame is drawn out to a sharp point. *In soldering*, a flame should be directed to the center of the joint and should be blown with sufficient pressure to bring the flame to a point. Use a piece of solder wire rather than a large stick of solder, thus avoiding the loss of considerable heat which takes place in heating the large stick of solder.

with a bit or blow torch until the solder melts and unites the two surfaces.

During the heating operation the surfaces should be held firmly together with clamps or other means. Figs. 5,193 to



FIGS. 5,193 to 5,196.—Method of sweating strap connector to wire. After cleaning, ap flux to parts to be united as in A; pick up solder on bit and cover surfaces with a thin film as in B; bend strap over wire as in C; hold bent part of strap down firmly with rod M, and heat with bit as in D. The pressure on rod M, should be continued until the solder has solidified.



FIGS. 5,197 to 5,200.—Method of insulating a joint or splice. A, take a turn of the rubber tape over the insulated end of the wire and in starting, hold end of tape with thumb; B, wrap tape over the exposed connection and continue a turn over insulation at end, pulling tape in wrapping until it stretches to nearly half its original width; continue wrapping in reverse direction building up the rubber covering until it equals the thickness of the wire insulation; C, cover the rubber tape with two layers of friction tape; D, insulation or taping completed.

5,196 illustrate the joining of a strap connector to a wire by sweating.

Insulating or Tap(e)ing.—To complete the various joints, taps and splices described in the two preceding chapters, the exposed wires must be insulated.

To insulate, the exposed wires are wrapped first with rubber tape until this covering is equal in thickness to the regular insulation. Then about two layers of friction tape are wrapped over the rubber tape. The method of taping is shown in the accompanying illustration.

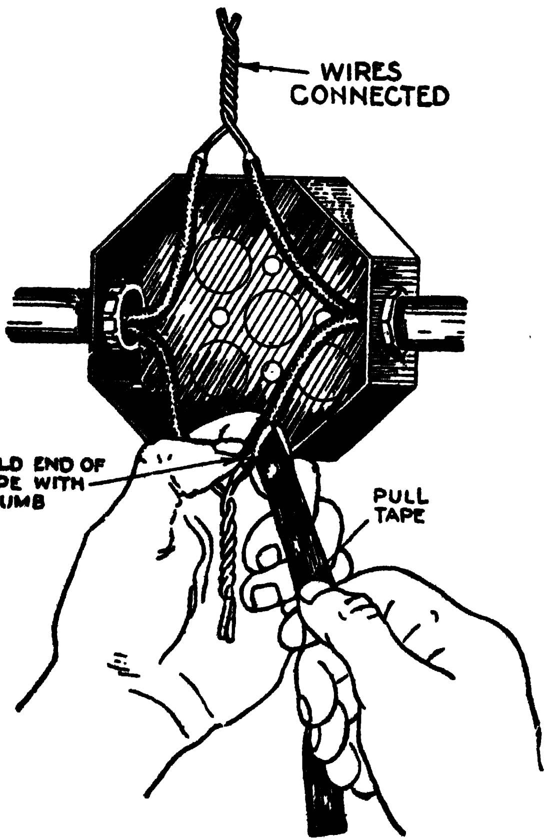


Fig. 3,201.—Method of starting tape in insulating a pig tail joint.

TEST QUESTIONS

1. *Give a definition of soldering.*
2. *What is solder?*
3. *What kind of solder should be used in electrical engineering, and why?*
4. *State briefly the theory of solder.*
5. *Name six operations to be performed in soldering.*
6. *What are the essential conditions for successful soldering?*
7. *Name four methods of soldering.*
8. *What is soldering flux and why used?*
9. *Describe the action of a flux.*
10. *What kinds of flux should not be used on electrical work and why?*
11. *What sometimes determines the kind of flux to be used?*
12. *What is the proper name for a so called soldering "iron"?*
13. *Describe the construction of a soldering bit.*
14. *What must be done preliminary to soldering?*
15. *Describe the method of tinning the bit.*
16. *How is the right temperature for a bit judged?*
17. *What happens if the temperature of the bit be too high?*
18. *How is the flux applied?*
19. *Upon what does the method of applying the solder depend?*
20. *Describe the "picking up" method of applying solder.*

21. *Describe the "melting on the work" method of applying solder.*
22. *What is the construction of a blow torch?*
23. *Describe the operation of sweating.*

CHAPTER 103

How to Read Plans

Wiring Terms.—There are a number of terms in general use relating to the work of wiring and the exact meaning of these terms is of importance to the electrician who installs any system of wiring. These definitions are from the National Electrical Code and are standard.

Definitions

Accessible.—(As applied to wiring methods, not permanently closed in by the structure or finish of the building; capable of being removed without disturbing the building structure or finish. (As applied to equipment.) Admitting close approach because not guarded by locked doors, elevation or other effective means. (See also Readily Accessible.)

Approved.—Acceptable to the authority enforcing this Code.

Branch Circuit.—That portion of a wiring system extending beyond the final automatic overload protective device of the circuit.

Lighting Branch Circuits.—Circuits supplying energy to lighting outlets only.

Appliance Branch Circuits.—Circuits supplying energy either to permanently wired appliances or to attachment plug receptacles, that is, appliance or convenience outlets or to a combination of permanently wired appliances and additional attachment plug outlets on the same circuit; such circuits to have no permanently connected lighting fixtures.

Building.—A structure which stands alone or which is cut off from adjoining structures by unpierced fire walls.

Cabinet.—An enclosure designed either for surface or flush mounting, and provided with a frame, matt or trim in which swinging doors are hung. (See cutout box.)

Cable.—A stranded conductor (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable).

Concealed.—Rendered inaccessible by the structure or finish of the building. Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them.

Conductor.—A wire or cable or other form of metal suitable for carrying current.

Controller.—A device, or group of devices, which serve to govern, in some predetermined manner, electric power delivered to the device governed.

Cutout Box.—An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper. (See cabinet.)

D.C. Neutral Grid.—A well grounded network of neutral conductors formed by connecting together within a given area all of the neutral conductors of a low-voltage direct-current supply system.

Dust-tight.—So constructed that dust will not enter the enclosing case.

Enclosed.—Surrounded by a case which will prevent accidental contact of a person with live parts.

Exposed.—Accessible; not concealed.

Feeder.—A stretch of wiring to which no connection is made except at its two ends.

Guarded.—Covered, shielded, fenced, enclosed, or otherwise protected, by means of suitable covers or casings, barriers, walls or screens, mats or platforms, to remove the liability of dangerous contact or approach by persons or objects to a point of danger.

Isolated Plant.—A private electrical installation deriving energy from its own generator driven by a prime mover.

Master Service.—The service conductors supplying a group of buildings under one management.

Motor Circuit Switch.—A switch used to stop a motor when at full running current, but not intended to open the motor circuit with stalled rotor current flowing. The switch may also serve to disconnect the motor and its controller when necessary for repairs, etc.

Outlet.—A point on the wiring system at which current is taken to supply fixtures, lamps, heaters, motors and current-consuming devices generally.

Panelboard.—A single panel, or a group of panel units designed for assembly in the form of a single panel; including buses and with or without switches and or automatic overload protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front. (See switchboard.)

Portable Appliance.—An appliance capable of being readily moved where established practice or the conditions of use make it necessary or convenient for it to be detached from its source of current by means of flexible cord and attachment plug.

Readily Accessible.—Capable of being reached quickly, for operation, renewal or inspection, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

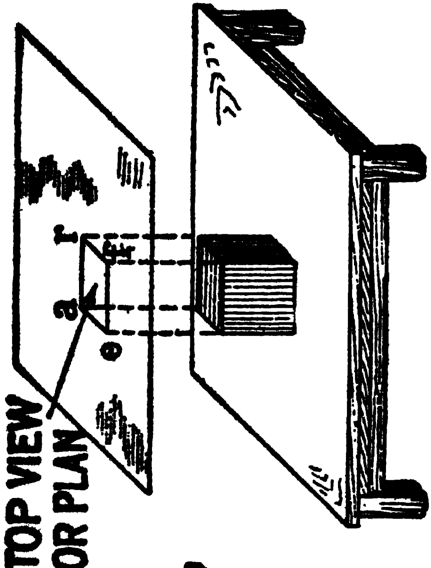
Secondary Neutral Grid.—A well grounded network of neutral conductors formed by connecting together within a given area all the neutral conductors of individual transformer secondaries of the supply system.

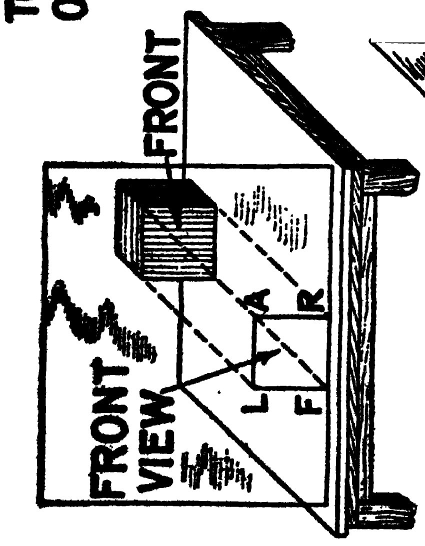
Service.—That portion of the supply conductors which extends from the street main or duct or transformers to the service switch, switches, or switchboard of the building supply.

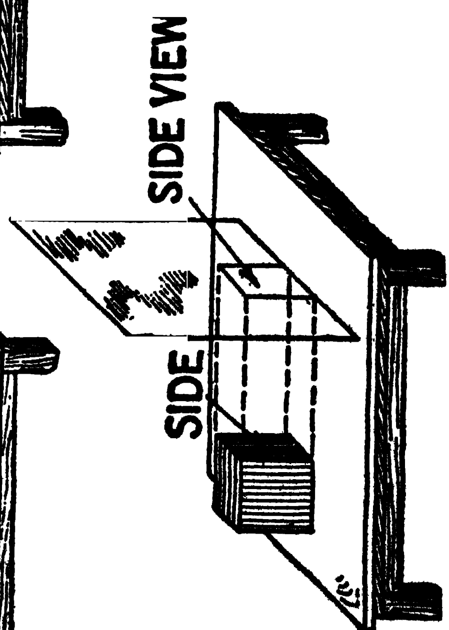
Sub-feeder.—Same class as a feeder, but is distinguished either by being one of two or more connecting links between the end of a single feeder, and several distributing mains, or by constituting an extension of a feeder.

Totally Enclosed Motor.—A motor which is so completely enclosed by integral or auxiliary covers as to practically prevent the circulation of air through the interior. Such a motor is not necessarily air-tight.

Voltage to Ground.—The voltage between the given conductor and that conductor of the circuit which is grounded; in ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit.







FIGS. 5,202 to 5,204.—Illustration of the various "views" of an object in orthographic projection by means of a pane of glass placed in the different planes of projection.

Waterproof.—So constructed or protected that moisture will not interfere with its successful operation.

Watertight.—So constructed that moisture will not enter the enclosing case.

How to Read Plans.—There are various ways of representing objects in drawings, such as:

1. Perspective;
2. Cabinet projection,
3. Isometric projection;
4. Orthographic projection;
5. Development of surfaces.

Of these methods, the first three may be classed as "pictorial" in that they show the entire visible portion of the object in one view, whereas the fourth requires several views to fully present the object and may be called "descriptive."

It is this latter method that is most generally used and which requires a little study to comprehend it. A knowledge of this method is necessary to read plans.

Orthographic Projection.—Isometric drawing and cabinet projection, while showing the object as it really appears to the eye of the observer, are neither of them very convenient methods to employ where it is necessary to measure every part of the drawing for the purpose of reproducing it.

Drawings suitable for this purpose, generally known as *working drawings*, are made by the method known as *orthographic projection*.

In cabinet or isometric projection, three sides of the object are shown in one view, while in a drawing made in orthographic projection, but one side of the object is shown in a single view.

To illustrate this, a clear pane of glass may be placed in front of the object intended to be represented.

In fig. 5,202 a cube is shown on a table; in front of it, parallel with one face (the front face) of the cube, the pane of glass is placed.

Now, when the observer looks directly at the front of an object from a considerable distance, he will see only one side, in this case only the front side of the cube.

The rays of light falling upon the cube are reflected into the eyes of the observer, and in this manner he sees the cube. The pane of glass, evidently, is placed so that the rays of light from the object will pass through the glass in straight lines, to the eye of the observer. The front side of the object, by its outline, may be traced upon the glass, and in this manner a figure drawn on it (in this case a square) which is the view of the object as seen from the front which in this case is called the *front elevation*.

One view, however, is not sufficient to show the real form of a solid figure. In a single view two dimensions only can be shown, length and height; hence the thickness of an object will have to be shown by still another view of it, as the top view or *plan*.

Now, place the pane in a horizontal position above the cube which is resting on the table, as in fig. 5,203 and, looking at it from above, directly over the top face of the cube, trace its outline upon the pane; as a result a square figure is drawn upon the glass, which corresponds to the appearance of the cube, as seen from above. This square on the glass is the top view of the cube, or its *plan*.

Fig. 5,204 shows the manner in which a side view of the cube may be traced; the glass is placed on the side of the cube, which rests on the table as before, and the outline of the cube on the glass in this position is called its *side elevation*.

Usually either two of the above mentioned views will suffice to show all dimensions and forms of the object, but to completely represent complicated objects, three or four views may be required.

In complicated pieces of machinery, however, more views, three and even more may be required to adequately represent the proportions and form of the different parts.

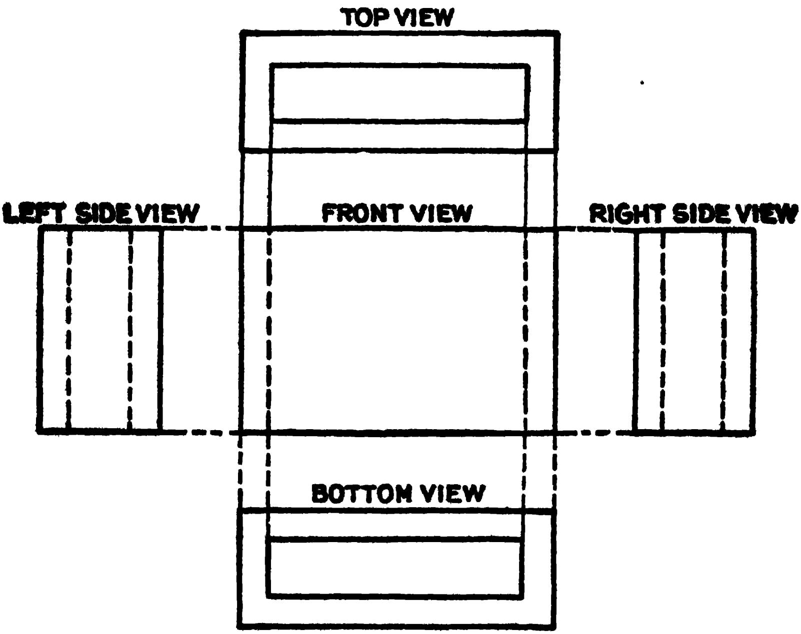
A drawing which represents the object as seen by an observer looking at it from the right side is called *the right side elevation* and a drawing showing the object as it appears to the observer looking at it from the left side is called *the left side elevation*.

In the case of a long object. a view at the end is called an *end view*.

A view of the object as seen from the rear is called the rear view or rear elevation. and a view from the bottom, the bottom view.

The different views of an object are always arranged on the drawing in a certain fixed and generally adopted manner, thus—

The front view is placed in the center; the right side view is placed to the right of the front view, and the left side view to the left; the top view is placed above the front view and the bottom view below it. The different views are placed directly opposite each other and are joined by dotted lines called *projection lines*.



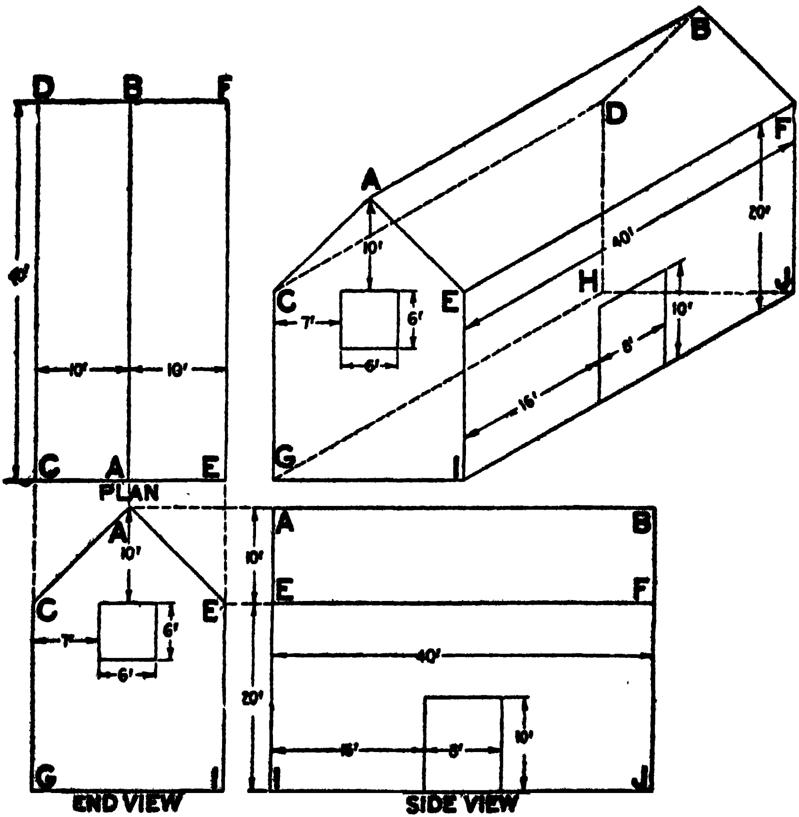
FIGS. 5,205 to 5,209.—Five views of an object as drawn in orthographic projection.

By the aid of projection lines, leading from one view to the other, as in figs. 5,205 to 5,209 measurements of one kind may be transmitted from one view to the other; thus, the height of different parts of an object may be transmitted from the front view to either one of the side views; in like manner the length of different parts of the object may be transmitted by the aid of projection lines, to the bottom view and top view.

It is often desirable to show lines belonging to an object, although they may not be directly visible. In figs. 5,205 to 5,209 the top view and the

bottom view show plainly that the object is hollow; looking at the object from the front or from the sides, however, the observer could not see the inside edges of the object, unless it were made of some transparent material.

In projection drawing it is assumed for convenience that all objects are made of such material, transparent enough to show all hidden lines, no matter from which side the object is observed; these hidden lines are represented in the drawing by dotted lines.



FIGS. 5,210 to 5,213.—Cabinet projection outline drawing of a barn, and same drawn in orthographic projection.

To illustrate the method of orthographic projection one problem is given.

Problem.—Draw plan, end and front views of the barn shown in fig. 5,211.

The plan will consist simply of a rectangle CDFE (fig. 5,210), the length of whose sides being obtained from the dimensions in the orthographic projections. The end view is projected down from points C,A,E, of the plan, being identical with the end in fig. 5,211, because it is here drawn in the "OX, plane" which is the plane of the paper and accordingly is seen in true size.

Similarly for the side view project over the points A,E,I., of the end view and lay off AB, EF, and IJ, equal to 40 ft., the elevation of these lines being obtained from the given dimensions. The door is laid out in a similar manner.

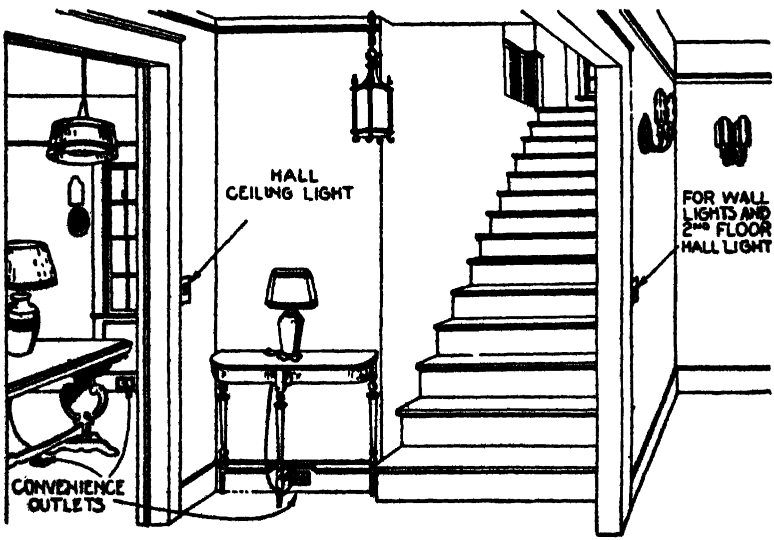


FIG. 5,214.—The vestibule and front hall.

Plans of a Dwelling.—To illustrate how to read blue prints

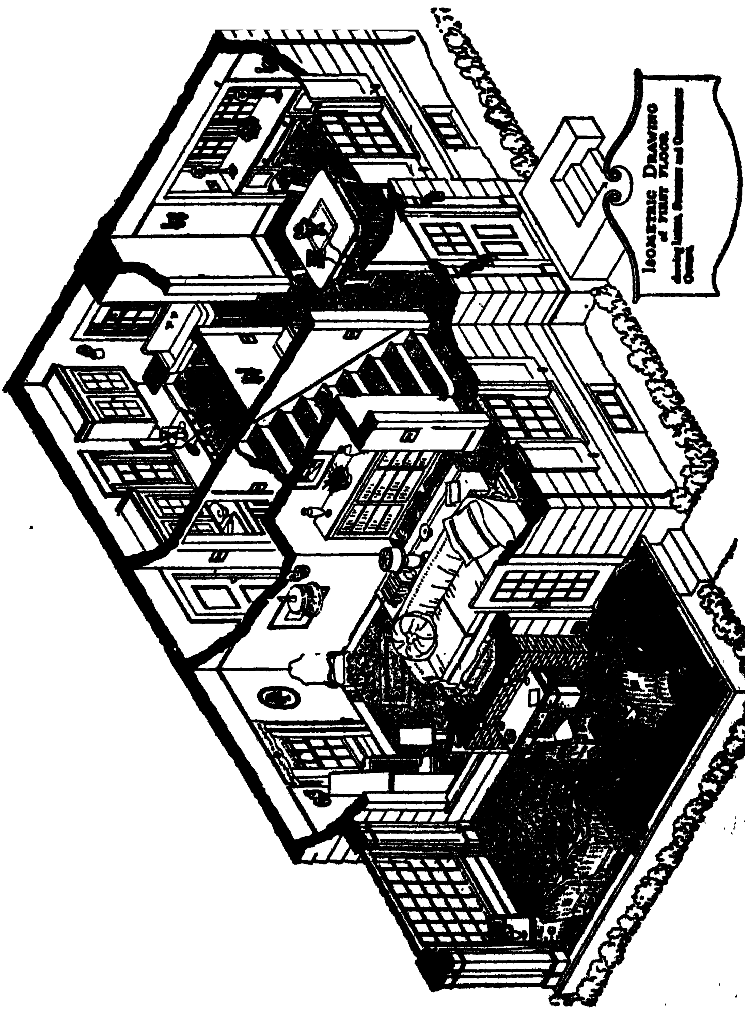


Fig. 5,215.—Isometric drawing of first floor showing lights, switches and convenience outlets.

First Floor Outlet Diagram.

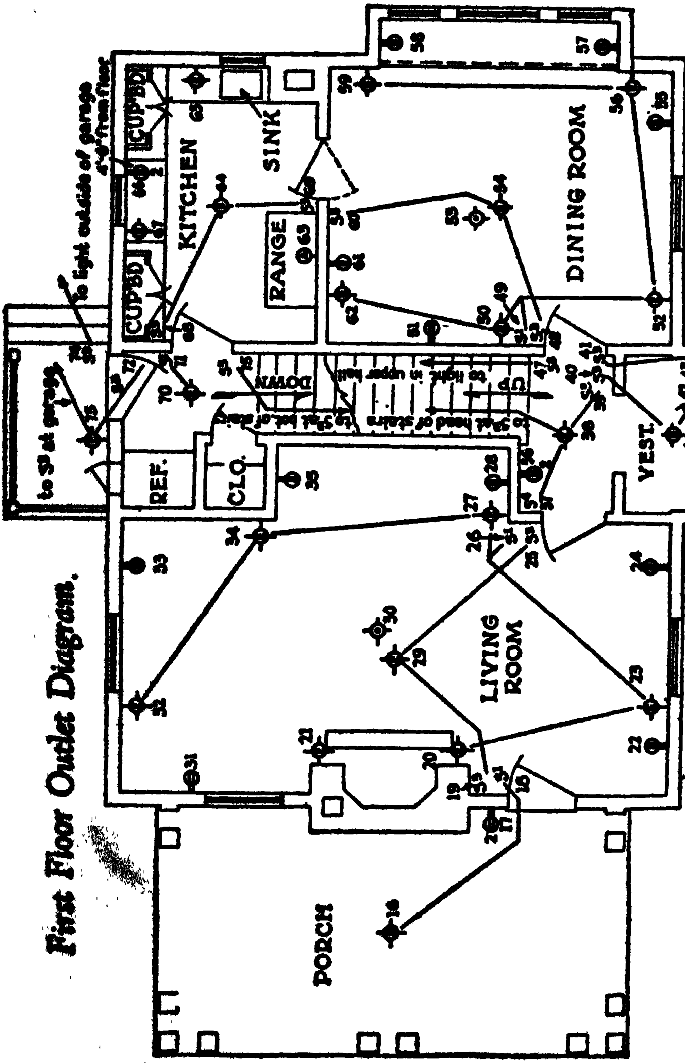


FIG. 5,216.—First floor plan or outlet diagram.

and especially how the electric wiring installation is indicated, a set of "plans" is here given.

With respect to the wiring, the symbols show the location of the outlets to which the wiring must be brought and the number of lights for which provision must be made. It is accordingly necessary to know the meaning of the symbols or to have at hand a table of these symbols as given conveniently in this chapter. To assist the student in reading the plans, the building is first shown in cut away *isometric projection*, fig. 5,215, which gives the general appearance of the interior the same as a photograph.

First compare the isometric drawing fig. 5,215 of the first floor with the plan, fig. 5,216.

Key for First Floor

= Ceiling Outlet for Extensions (Elexits)

= Wall Outlets for Extensions (Elexits)

= Wall Outlet

= Single Convenience Outlet

$_2$ = Double Convenience Outlet

= Floor Outlet

= Range Outlet

S^1 = Single-pole Tumbler Switch

S^2 = Double-pole Tumbler Switch

S^3 = Three-way Tumbler Switch

S^4 = Four-way Tumbler Switch

NOTE.—Where Elexits are indicated other types of outlets may be substituted.

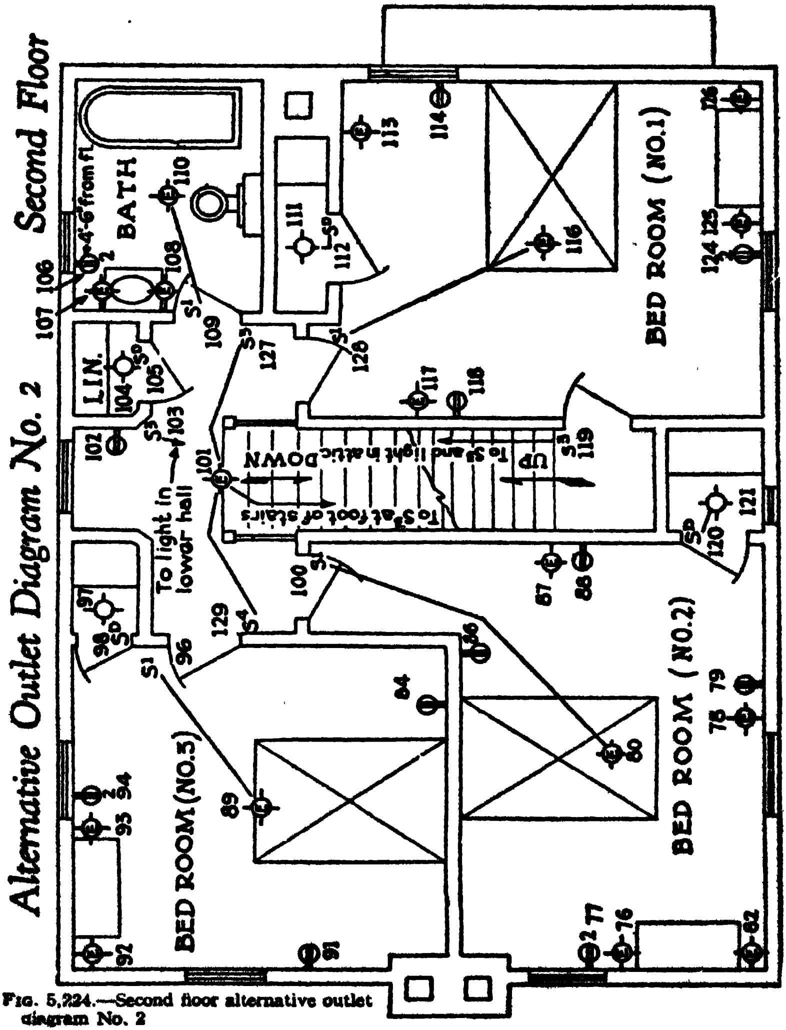


FIG. 5,224.—Second floor alternative outlet diagram No. 2

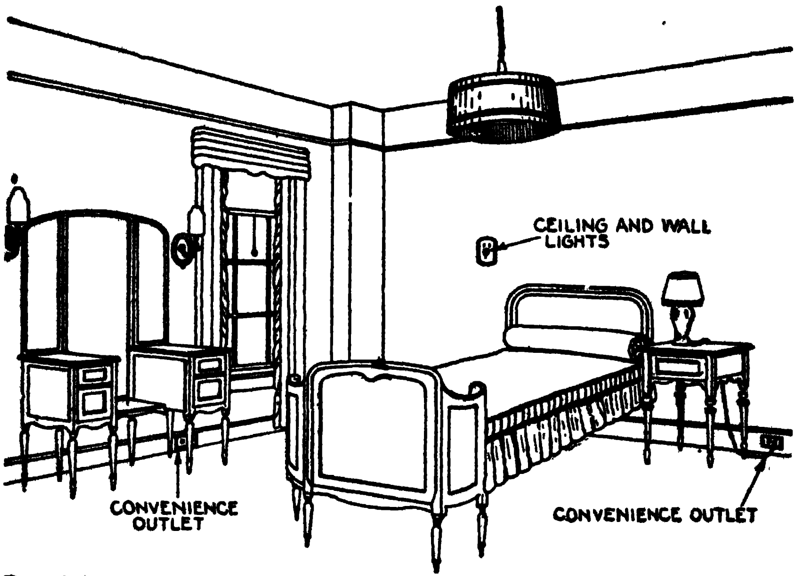


FIG. 5,225.—The bed room.

TEST QUESTIONS

1. *Give definitions of wiring terms.*
2. *Name five ways of representing objects in drawing.*
3. *Are pictorial methods or the descriptive method used?*
4. *What is orthographic projection?*
5. *What are the names given to orthographic projection?*
6. *Draw diagrams showing the three "views" employed in representing an object.*
7. *Give the names of the three "views."*
8. *What is assumed in making projection drawings?*
9. *Name the principal elements of a wiring system.*

CHAPTER 104

Farm Wiring

General.—The use of electric light and power on farms is constantly increasing. The fundamental reason for additional usage of electricity is primarily to save labor, cut operating costs and provide for a higher living standard by means of labor saving machinery and an ample well-planned lighting system.

It is not possible, however, to obtain the fullest possible use of electricity without a *well-planned wiring system*. The basic requirements of a well-planned farm wiring system are:

1. Adequate wire capacity and safety;
2. It must be easily expanded and economical.

The requirement of safety will be satisfied by compliance with the *National Electrical Code*, the others depend upon careful planning.

A farm wiring system should be planned and installed with outlets conveniently located for the use of modern electrical farm equipment, and with a distribution system of services and feeders that delivers proper voltage and to which changes and additions can be made easily and at minimum expense. If it be so designed, it will meet the requirements of adequacy and easy expansion and consequently the requirement of economy.

Because of the fact that farm residence wiring and interior lighting methods do not differ appreciably from home wiring in general, no attempt has been made in this chapter to cover this part of the electric system.

Wiring Systems.—The general plan of a farm wiring system depends upon the source of electrical energy. For farm service there are generally two sources available, namely:

1. The public utility power line;
2. Individual farm lighting plants.

The generating station of public utility systems usually supply 60 cycle alternating current at 115 and 230 volts, single phase, two or three wires. Individual plants differ, but direct current at 28 to 32 volts and 115 volts are common, although some types provide 115 volts alternating current.

For the 32 or 115 volt supply a two-wire system is required, while for 115-230 volts supply a three-wire system is usually used, making both voltages available. Individual branches of this system may be either two- or three-wire.

The three-wire system is usually the most satisfactory for farm service because of the two voltages and the additional power available. The individual farm power plant is designed primarily for lighting purposes, whereas the public utility supplies power for motors, electric ranges, water heaters, etc.

The logical steps in planning a farm wiring system are as follows:

1. Plan the number and location of outlets;
2. Determine the amperage of each lamp, motor or appliance;
3. Determine the type and size of service to install;
4. Determine the number and size of branch circuits;
5. Select the types of wiring materials, switches and fixtures.

In general the public utility power company will bring its distribution line up to a point near the farmstead, usually along the road, placing a transformer near the entrance to the farmstead and extending secondary lines to a pole or building on the farm, at which point metering equipment will be installed.

From the metering point, energy is distributed within the practical electrical limitations on the secondary voltage. Under most conditions this will encompass an area within 300 feet from the point of supply based on 2% voltage drop on the outside wiring system. If service be needed at locations beyond this radius the electric utility should be consulted.

As a matter of economy in wiring the electric service should enter and the meter should be located as near as possible to the electric load center of the farmstead.

Whether the meter is located outdoors or indoors depends in most instances upon the rules and regulations of the electric utility company.

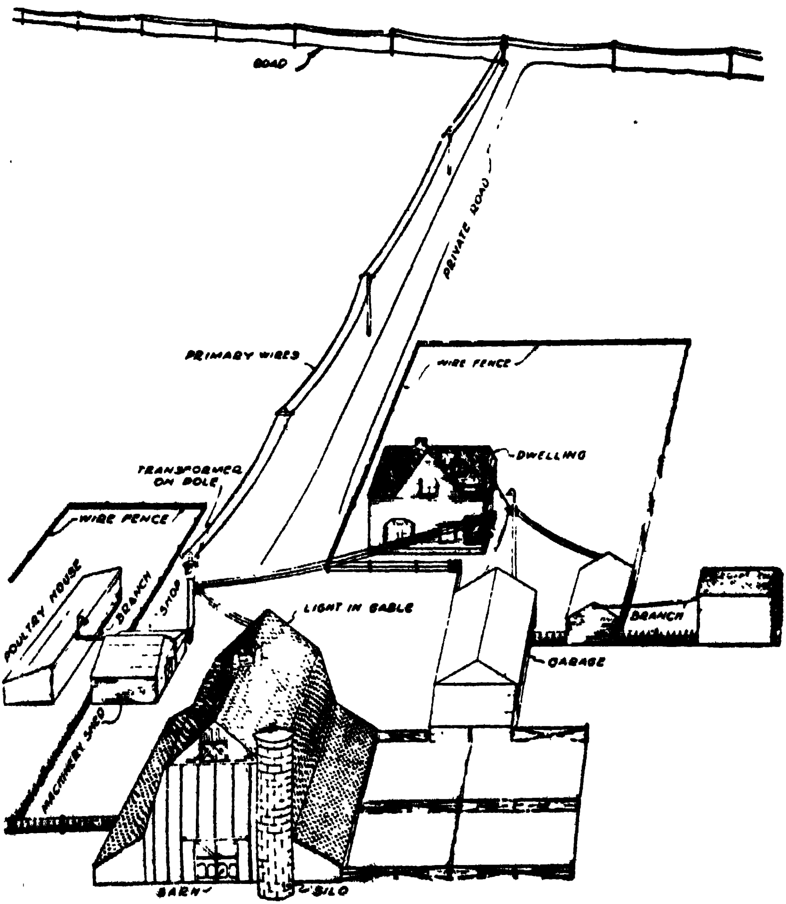


FIG. 5,365.—Illustrating arrangement of public utility secondary service wires for a group of farm buildings with the wires arranged for service by one main feeder.

Lighting and Wiring of Farm Buildings

Barns.—There are many types of barns, depending on the individual farm. The most common are the *dairy*, the *horse*, the *cattle*, the *sheep*, the *hog* and the *general barn*. Typical barn construction seldom allows the entrance of much daylight and since much of the regular work in the barn is done during the hours when there is little or no daylight available, good illumination is necessary.

The Dairy Barn.—Usually dairy barns are arranged in a series of alleys, that is, one set for *feeding* and the other for *milking* and *cleaning*.

This lends itself readily to the installation of outlets down the center of each alley with units spaced 12 to 20 feet apart.

With reference to fig. 5,366, showing the wiring plan and switch location of a typical dairy barn, the cleaning alley should have one outlet for every 12 feet on center line of the alley or slightly off center if necessary to clear manure carrier.

The feeding alley should have one outlet every 20 feet on center line of alley. The cleaning alley outlets should be controlled by wall switches, separate from switches controlling feeding alley outlets.

These requirements will be satisfactory regardless of whether cows are in two rows facing out or two rows facing in. In face-out barns, an alternative arrangement for cleaning alley is to install two rows of lights between center line of alley and back edge of gutter, 16 feet apart in the row for four-foot stanchions, outlets in one row being two stall spaces or eight feet ahead of those in other row.

In stall barns where cows are milked and in milking rooms, desirable intensities are at least one-foot candle at milker and two-foot candles at scale when feed or milk of individual cow is weighed. To approximate this level of illumination requires at least 100 watt lamps on 12 foot centers, or 60 watt lamps on 16 foot staggered arrangement.

Convenience Outlets.—When pipe line milker is used, outlets for clippers, immersion heaters, heat lamps, etc., should be installed in cleaning alley, spaced one outlet for every 30 feet.

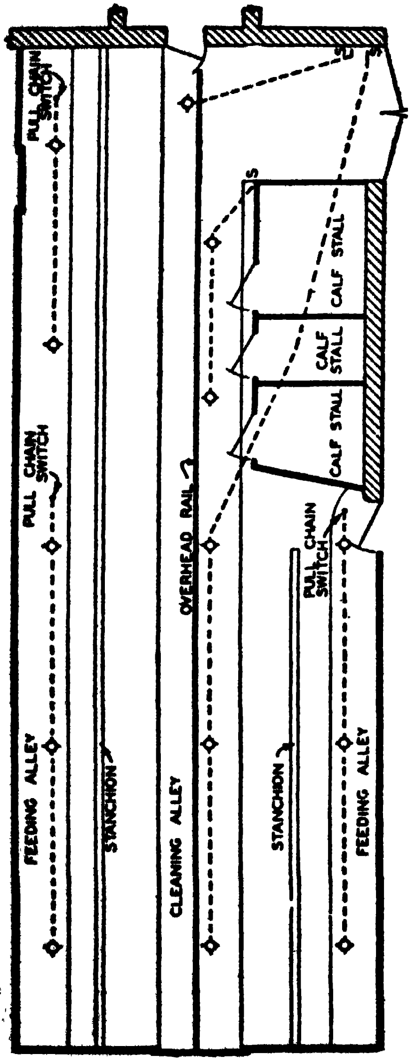


FIG. 5,366.—Showing wiring plan and switch location for typical dairy barn.

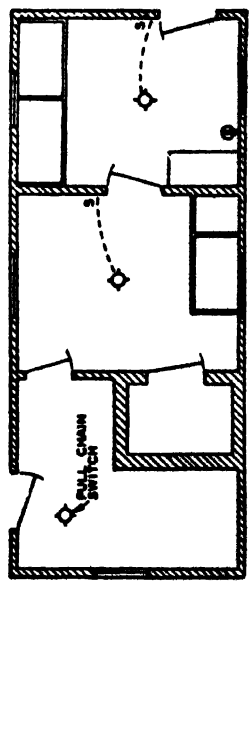


FIG. 5,367.—Showing wiring plan and switch location for typical milk house.

When portable milker is used, outlets for portable milker, clippers, immersion heaters, infra-red lamps, etc., should be installed in cleaning alley, spaced one outlet for every 15 to 20 feet. Minimum circuit wire No. 12.

In barns where cows face out, one row of convenience outlets in central cleaning alley will serve two rows of cows.

In a stable with two rows of cows facing out, convenience outlets may be installed on posts or may be installed in the form of cord connectors placed through the center of the cleaning alley and suspended a convenient height above the floor on heavy duty cord. If there are two rows of cows facing in, convenience outlets may be suspended from ceiling or placed on wall back of cows and as high above floor as can be reached conveniently.

Outlets for electric window and door screens will be found convenient.

Special Purpose Outlets.—The Outlet for pipe-line milker should be 230 volts (except where portable milker is to be used). Circuit wire size depends on motor horse power. Minimum No. 12 wire.

Outlet for ventilating fans (in regions where climate and barn structure make ventilation necessary).

Ventilating fans of less than ¼ *h.p.* may be connected to lighting or convenience outlet circuits.

The Cattle Barn.—The cattle barn is usually a closed area containing feed troughs. In general a row of lamps in reflectors over the troughs will give adequate lights at the troughs and over the rest of the barn floor. In large barns, additional outlets are necessary and, therefore, general lighting for the entire area is recommended. With spacing of 10 to 12 feet the 40-watt lamp is used, while with spacing of 12 to 15 feet the 60-watt lamp is necessary.

Wall switch control for feed trough outlets, separate from switches controlling other outlets should be provided.

The Horse Barn.—Normally the horse barn consists of feeding and cleaning alleys similar to the dairy barn. The lights may, therefore, be arranged in the same manner as that for the dairy barn, with the added precaution that the spacing

in the cleaning alleys be so chosen that the units come opposite alternate stall partitions, since they are usually solid in contrast to the open stanchions of the dairy barn. See fig. 5,368. As in the dairy barn there are individual stalls at one end of the barn.

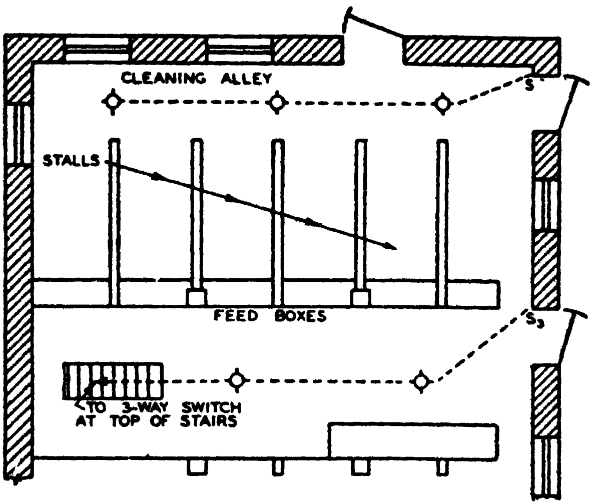


FIG. 5,368.—Wiring layout and switch location in a typical horse barn.

The Sheep Barn.—This may be of the open or closed type. The open sheds are enclosed to a height only sufficient to prevent the sheep from getting out and to protect them from the wind. Closed sheds are of the common barn construction. In wide sheds there are usually two rows of feed troughs with a center runway. Here general lighting supplied by 40 or 60 watt lamps in suitable reflectors, mounted at the ceiling, is best. In narrow sheds a row of similar units directly over, or not more than four feet behind the single feed trough will be found satisfactory.

One convenience outlet for lamb brooders should be provided for each pair of pens. Outlets should also be provided for water warmers, adjacent to the watering troughs. Special outlets for sheep shearer should be provided on wall or post at location where shearing is done.

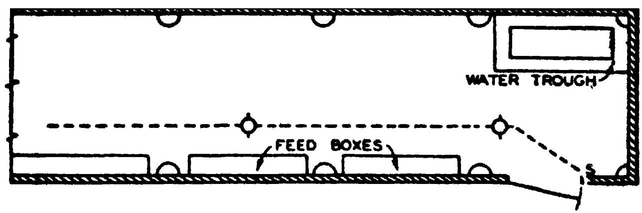


FIG. 5,369.—Typical sheep barn lighted by one row of units.

The Hog Barn.—The hog barn, especially in large sizes and community types, is somewhat similar to the enclosed sheep barn. The lighting is, therefore, similar.

The General Barn.—This usually contains a small space apportioned to each of the general activities of a farm. The lighting described under the specific types of barns should be applied to the individual portions. In the upper portions of most barns the hay mow is located.

In order to eliminate all possible fire hazards and also to provide space, it is customary to provide a 100 or 150 watt lamp for each mow placed high against the ceiling in *shallow dome*, *angle* or *R.L.M.* dome reflectors.

When properly placed, the units should light the driveway or floor space located below or between the mows.

The Silo.—Most barns, especially those with cattle, have a silo in which food is stored for the stock. The silo is built in the form of a high circular tower with an attached chute. This is usually a dark place where there is a considerable chance of missing a step and falling when climbing. The R.L.M. standard dome with a 100-watt lamp will supply sufficient illumination.

It may be mounted at the top of the silo or at the top of the chute. In the latter case it should be tilted slightly towards the side of the silo so that it provides some light for the interior. It is also possible to mount the same reflector on a pulley so that it can be raised or lowered in the chute as the work demands.

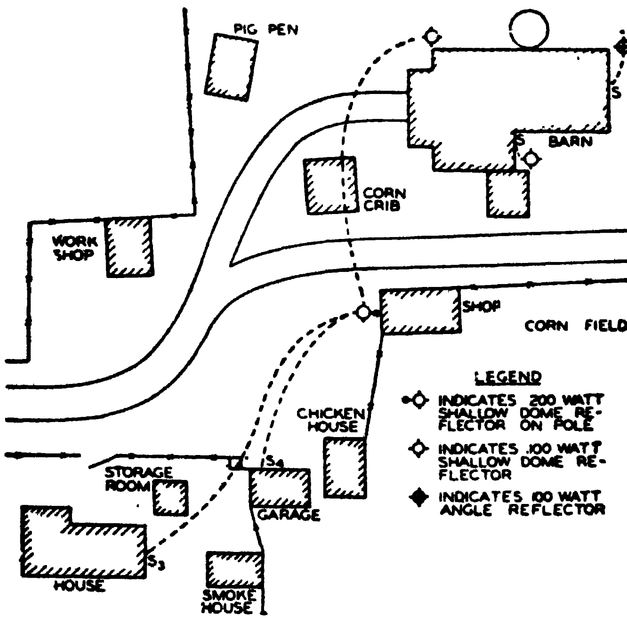


FIG. 5,370.—Typical farmyard lighting arrangement.

Yard Lighting.—The arrangement of farm buildings results in large open areas between and around the buildings, fenced off from the rest of the farm land. In order to move about from one building to another after dark and during the early morning hours, it is desirable and necessary to have an adequate system of yard lighting.

Mazda protector lamps or flat dome reflectors equipped with 100-, 150- or 200-watt frosted lamps may be used for this purpose. They may be suspended from brackets on the side of the buildings or on poles. In any event, they should be as high as reasonably possible in order to secure a wide distribution of light. Their exact number and location depend on the individual farm.

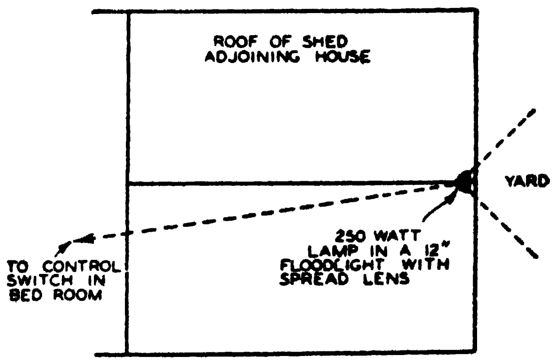


Fig. 5,371.—Showing a simple and effective protective lighting arrangement for a farm.

The control of this outdoor lighting depends upon the location of the lights and the habits of the users. In all cases three-way switches should be used between the kitchen and the barn or garage for the lighting of the main area between these buildings. Other lights may be controlled by switches inside the entrance of the nearest building.

It is sometimes necessary to provide against thieves and other night prowlers. To a certain degree the yard lighting will serve this purpose. Frequently, however, additional means of lighting certain areas are desirable. This may be accomplished by floodlights. As a rule, floodlight projectors using the 200-watt general or the 250-watt floodlighting lamp are large enough. They should be located near or on the farm house, directed so as to make any specific area clearly visible to the person controlling the light from the farm house.

Switch Control.—The proper control of the various lights in any farm interior adds immeasurably to the convenience of electricity. General rules are hard to give since the location and type of switch depends largely on the size and shape of the room, and the relation of the room to the rest of the building and to the rest of the farm. It can safely be said that the farmer should be able to precede himself with light when entering all frequently-used doors and turn the lights off when leaving through these doors.

If there are two doors opening into the same room, both frequently used, three-way switches should be installed, enabling the same lights to be turned on or off from either door. Whether or not all the lights in a room are turned on at the same time depends on the size of the room.

Pull chain switches are often satisfactory for individual lights, and sometimes for groups of lights if the total load (wattage) is not too great. The individual plan drawings throughout the chapter give typical arrangement of switch control.

Poultry Structures

The poultry structure usually includes the *hen house*, the *incubator room*, the *brooder house* and the *feed room*, all of which may or may not be under the same roof, depending upon the size of the flock.

In the operation of poultry houses, regardless of size, a properly planned lighting system will aid in the increase of egg production as well as assist in the proper care of the flock and the maintenance of the houses.

The Laying House.—It should be noted that installation practices for lighting of poultry laying houses as an aid to stimulating egg production will vary, not only as to type of poultry, whether it be hens, ducks or turkeys, but also as to geographic regions. In addition, practices differ with size and design of laying house and also with method of lighting operation.

It has been found by experience that hens become very inactive during the long winter season and that extending the daylight period by means of artificial illumination will increase the activity. Increased activity in scratching and eating aids to increase egg production.

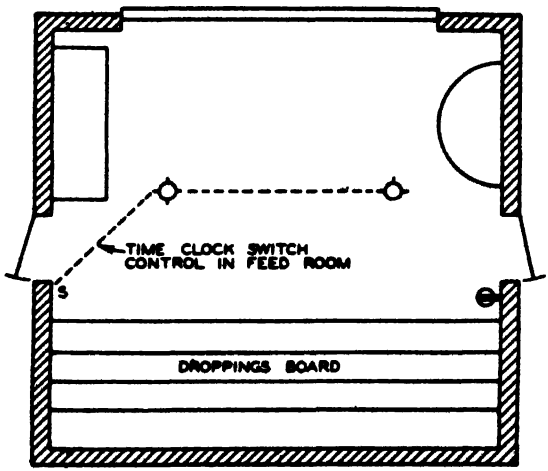


FIG. 5,372.—Showing usual lighting arrangement for the hen house.

The methods used to provide this additional illumination differ, but are usually grouped into three periods of the day, namely:

1. Morning lighting;
2. Morning and evening lighting;
3. All-night lighting.

The following recommendations given with respect to the various method of lighting are not concerned with hours of operation, since these will best be found by experience, but only with the number of outlets, their location and method of control.

Morning Lighting.—The minimum illumination provided should be one outlet for every 200 square feet of floor area.

In a house or pen 20 feet deep, one row of outlets 10 feet apart should be installed along a line midway between the front of the house and the dropping board. Outlet at end of row should be five feet from end of pen.

Lights should be suspended six feet above floor, equipped with 40 watt lamps and reflector 16 inches in diameter and four inches deep. Cover reflector surface with three coats of aluminum bronze paint or install reflectors made with aluminum bronze finish, as that portion of light most beneficial to birds is best reflected by aluminum surface. When deeper reflectors are used, provide one-inch socket extensions to bring bottom of lamp even with bottom of reflector. This increases spread of light, so that roosts will be illuminated, causing hens to leave roosts during lighting period.

With roosts at back of pen, place outlet for each 200 square feet with out lets in two rows, staggered with respect to each other, wattage same as pre-

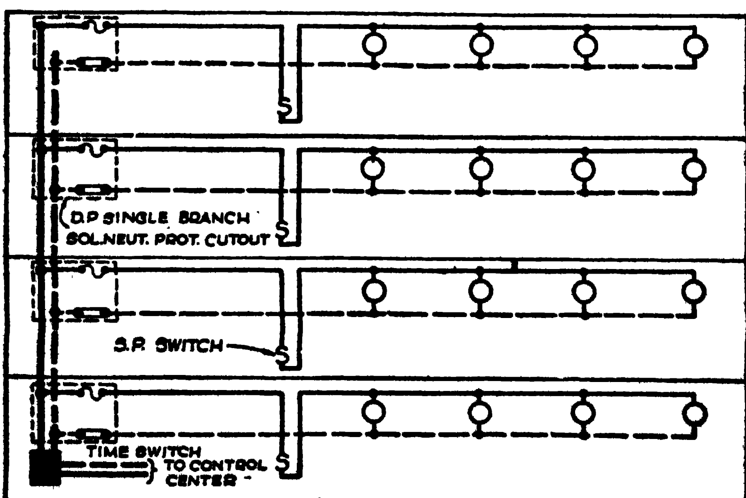


FIG. 5,373.—Illustrating *time switch control* for several floors or pens with local switches to cut off individual pens, *for morning light only*.

vious. An alternative arrangement is to install one outlet for each 300 square feet. One row of outlets 15 feet apart should be installed along a line midway between front of house and dropping boards. Outlet at end of row should be not over eight feet from end of pen.

Time Switch Control for Lighting Outlets.—In multi-story or large poultry houses where the number of lighting outlets is in excess of the number which can be installed on a single branch circuit, a heavy duty circuit can be run through the time switch to the different floors or pens with local circuit protection and switch control at each floor or pen. See fig. 5,373.

Where it is desired to control lights on any floor or in any pen, independently of the time switch, see fig. 5,374. Where different time schedules are needed for pens of old birds as compared to pullets, more than one time switch will be needed.

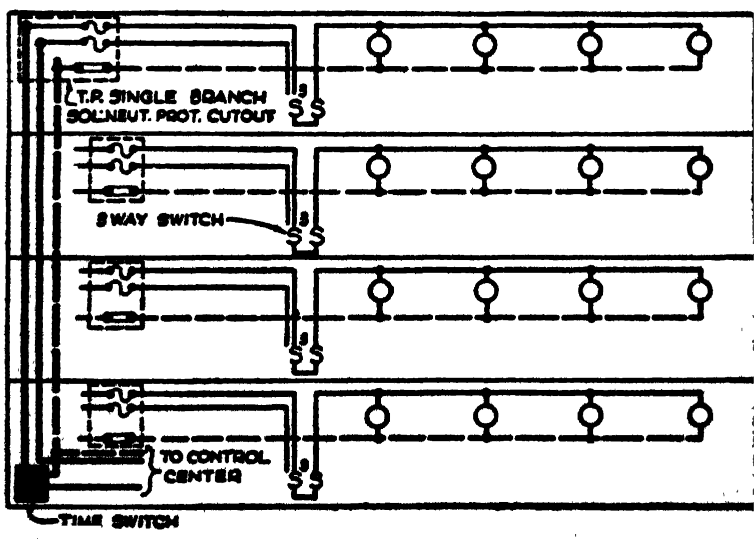


FIG. 5,374.—Time switch control for several floors or pens with local switch ol to transfer lights to either time-controlled or live feeder, *for morning light only.*

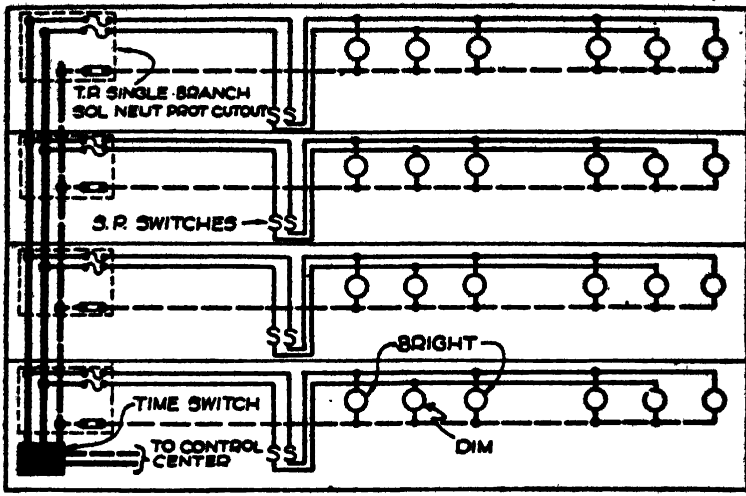


FIG. 5,375.—Time switch control for several floors or pens with local switches to cut off individual pens, *for morning and evening light.*

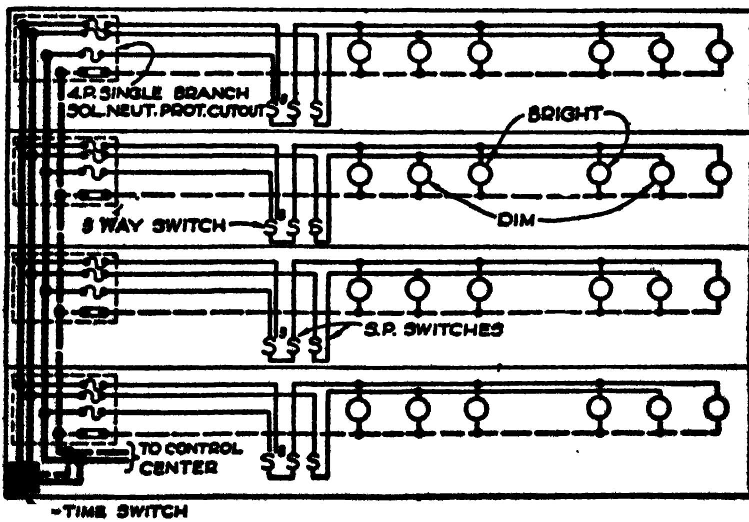


FIG. 5,376.—Time switch control for several floors or pens, with local switch control to transfer bright lights to time controlled or live feeders and local switch control for dim light, *for morning and evening light.*

Morning and Evening Lighting.—*Bright light outlets* should be installed in the same manner as for *morning lighting*.

Dim light outlets should be installed on separate circuit, one outlet for every 400 square feet of floor area and placed in a row slightly back of bright light outlets, toward roosts; wattage 10 to 15 watts each.

All Night Lighting.—Arrangement of lighting outlets should be the same as for *morning lighting;* wattages 15 to 25 watts each outlet. Switch control for each pen.

Where some pens are to be operated on *all night lighting* and others on *morning* or *morning and evening lighting*, use wiring methods shown in figs. 5,375 or 5,376.

Convenience Outlets.—In climates where temperatures require warming of poultry drinking water in cold weather, install one outlet for every 400 square feet of floor area, but at least one outlet for each pen. Place outlets on posts or walls at least three feet above floor to minimize collection of dust on contacts or suspend from ceiling on pendant cord connectors. No. 12 wire minimum (10 outlets maximum per circuit).

The Incubator Room.—Since light must be provided on the front of the incubators, the arrangement will determine the location of the lighting units. In other parts of the room, if a large one, general lighting is necessary. Standard dome

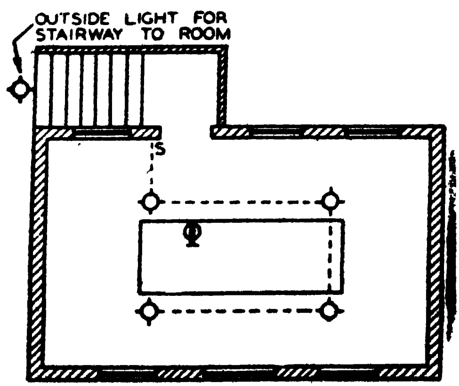


FIG. 5,377.—Illustrating wiring layout and switch control for typical incubator room located under the hen house.

reflectors with 25-, 40- or 60-watt lamps mounted close to the ceiling may be used.

The Brooder House.—This is the house in which the chicks old enough to be transferred from the incubator are kept. It can usually be lighted by one 25- or 40-watt lamp mounted close to the ceiling in the center of the room. When water warmer is used, convenient outlets should be installed on wall or post convenient to location of drinking fountain.

When ultra-violet radiation is employed in the brooder and hen house special outlets should be provided for this purpose. It is recommended that convenience outlets serving brooders be fed by a special feeder by at least three No. 10 wires with individual circuit protection for each brooder. The load should be balanced as far as possible by connecting outlets alternately to one or the other ungrounded conductors.

The Feed Room.—This will usually contain bins in which feed is kept and auxiliary space for grinding, mixing, etc. The bins, if large enough, should be individually lighted by 25-watt lamps; otherwise the general lighting as applied to the auxiliary space should be so installed that all bins receive some light. The best arrangement is to have a unit opposite alternate bin partitions.

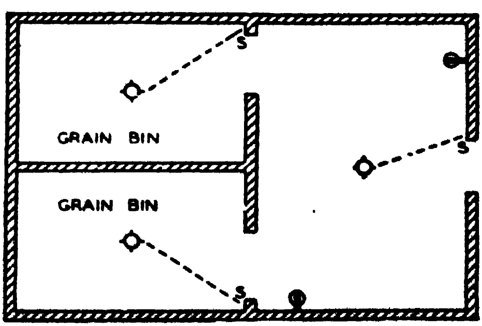


FIG. 5,378.—Typical layout and wiring for a large feed room

Miscellaneous Rooms.—These consist of egg storage and handling room, poultry, cleaning and dressing rooms, etc.

The general lighting in such rooms should consist of one outlet for every 200 square feet of floor area, in addition to two outlets over each working space to prevent shadows. All of these outlets should be wall controlled.

Special convenience outlets should be provided for each egg cooler, egg candler, egg cleaner, egg grader and humidifier fan.

Special Purpose Outlets.– When poultry farming is done on a large scale, special outlets should in addition be provided for poultry scalder (1,000 to 4,500 watts); outlet for waxer (1,000 watts); outlet for wax reclaimer (1,500 watts); outlet for picking machine (¾ to 1½ *h.p.*); outlet for refrigerating equipment (½ *h.p.* and up).

TEST QUESTIONS

1. *What is the fundamental reason for the additional use of electricity on farms?*
2. *What are the basic requirements for a well-planned farm wiring system?*
3. *Name the two systems of electric supply usually found on farms.*
4. *What is the maximum voltage drop usually allowed in the outside wiring system?*
5. *Describe the usual arrangements of lights in dairy barns.*
6. *Where should the lamp be placed in the silo?*
7. *Why is it desirable to provide night lighting in poultry structures?*
8. *How is night lighting in poultry structures usually controlled?*

CHAPTER 105

Open or Exposed Wiring

This method of wiring possesses the advantages of being economical, durable and accessible. There are two methods of open or exposed wiring, known as:

1. Knob wiring, and
2. Cleat wiring.

Open wiring on insulators, comprising insulated conductors mounted on porcelain or cleat insulators is the simplest and most economical of all wiring methods.

It is highly desirable for installation in all buildings of wood frame construction, including buildings with wood frame and masonry or stucco veneers. It is recommended for residences, including single- and multi-family dwellings, commercial and industrial structures. It may be installed in the free air spaces of walls, partitions and ceilings or in these same spaces when thermal insulations of non-conducting materials fill the voids. For most types of occupancy, it is much more desirable than any other method of wiring construction.

In wet locations, including sea coast areas, it is especially desirable because it is not affected by rust and salt atmosphere. In flood areas it is quickly restored to service without damage. Where chemicals and corrosive atmospheres are present this type of wiring prevents deterioration and in industrial plants it provides rapid cooling of conductors and enables the use of smaller sized wire, saving materials and cutting costs. For areas where poor or non-permanent grounding exists the absence of dangerous conducting metals is particularly desirable.

Wire Spacing.—The spacing of wires from each other and from the surface over which they run, depends on whether the wires will be permanently exposed, or concealed inside the walls.

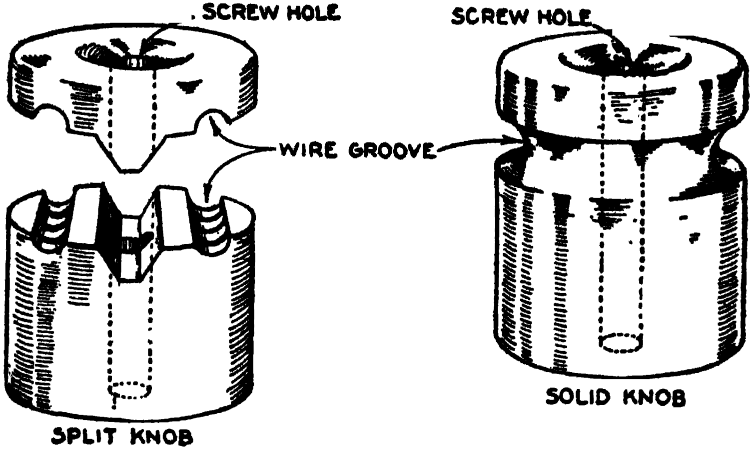
Open conductors shall be separated at least two and one-half inches from each other. In dry places for voltages not over 300 volts, the conductors shall be separated not less than one-half inch from the surface wired over.

For voltages from 300 to 600 volts, the conductors shall be separated at least one inch from the surface wired over and except as provided in the Code shall be separated at least four inches from each other. In damp or wet locations, a separation of at least one inch from the surface wired over shall be maintained.

Types of Wires.—In dry places, conductors may be any one of the following types: R, RH, RW, RU, T, TW, SBW, SB, AA and AIA. In damp or wet locations or in locations especially subject to moisture wires shall be rubber covered. In concealed wiring, types R, RH, RW, RU, T and TW shall be used.

Knobs and Cleats.—There is a great variety of knobs and cleats available to suit various sizes of conductors and conditions of wiring. Porcelain cleats, knobs and tubes, figs. 5,226 to 5,241, serve to illustrate the various types of supports used on open wiring systems. Two- and three-wire cleats are used with small conductors No. 12 to 8 for voltages not exceeding 300 volts.

Three-wire cleats are used on three-wire systems with the neutral conductor in the center and not over 150 volts to either outside conductor. Single cleats are used for higher voltages



FIGS. 5,226 and 5,227.—Illustrating typical knobs used as wire supports in open wire installations.

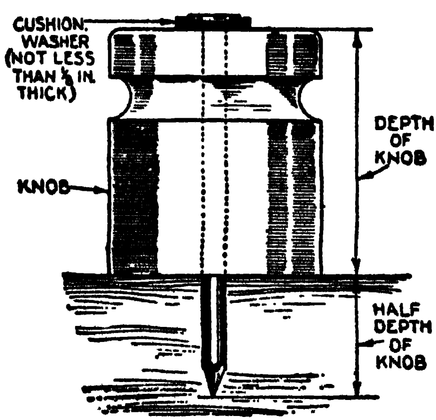
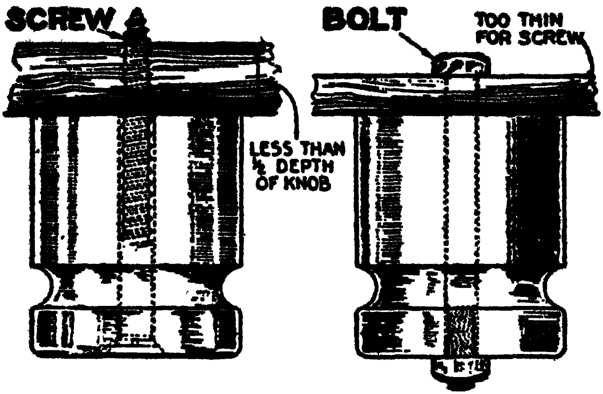
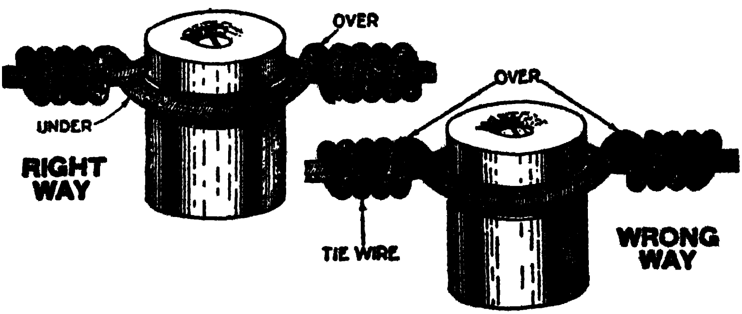


FIG. 5,228.—Method of fastening knob with nail. Note that the nail must penetrate the wood not less than one-half the depth of the knob.



FIGS. 5,229 and 5,230.—Screw and bolt method of fastening knobs. If the support be less than half the depth of knob, use a screw as illustrated. If, on the other hand, the support be too thin for proper fastening with screw use a bolt and nut for fastening of knob.



FIGS. 5,231 and 5,232.—Right and wrong method of tying wires to grooved knobs, called *tying in*. In fig. 5,231 one end of the tie wire passes over the wire, the other passes under. Pliers must be used so that the wires will be tightly secured. In tying the wires, the first and last knob should be tied in and the intermediate knobs tied in last. Where the wires are of large size, a block and tackle should be used, care being taken not to pull too tight as this will stretch the wire. The tie wires should be of solid wire and of the same size as the wire to be secured, one wire is passed underneath the wire and the other wire is passed over so that it is secured at both ends. Pliers should be used as the tie wire cannot be properly secured by hand.

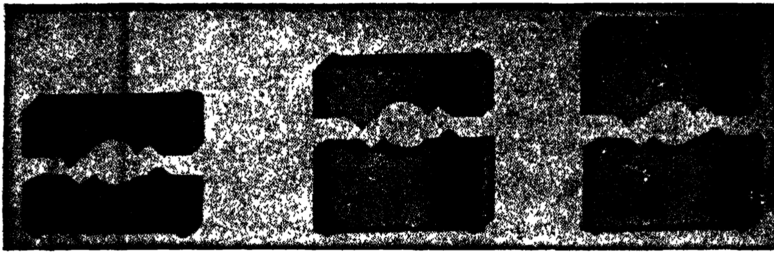
and larger conductors, also in all cases where variable spacing of conductors is required.

Wires must be supported by porcelain insulators at least every four and one-half feet. There must be a support within eight inches of every outlet box or within six inches of a tap made outside of a box.

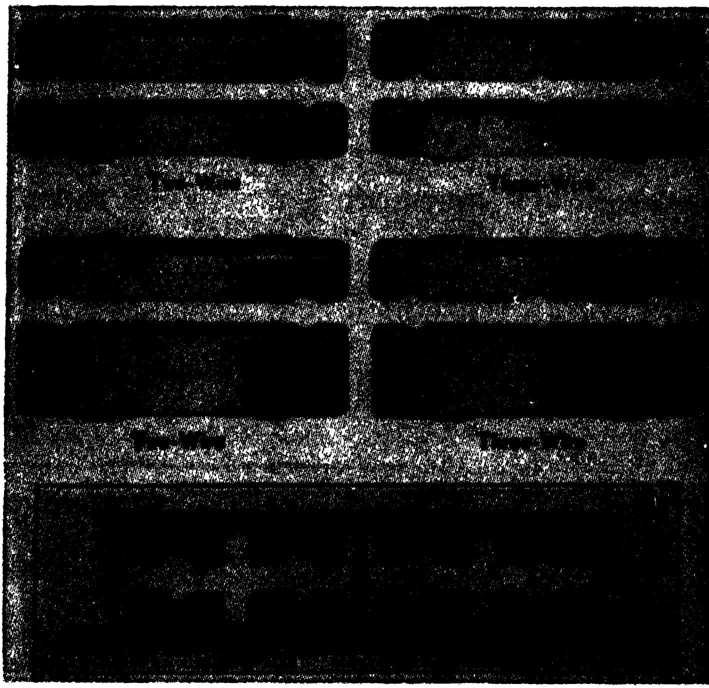
In industrial and commercial work, if the building is of "mill construction" with heavy ceiling timbers, wires No. 8 and heavier may be run from timber to timber without support except at the timbers. Such wires must be spaced at least six inches apart as shown in fig. 5,244. Many buildings fall into this classification, and permit porcelain protected open wiring, using smaller wires because of better heat dissipation. Thus there is a substantial saving of copper and rubber in the wires, plus the metal of raceways, not to mention installation time.

Corner Wiring.—In running wires around a corner, it is best to use knobs as shown in fig. 5,242. In open work cleats may also be used as shown in fig. 5,243, but a porcelain tube must be slipped over the outside wire, because at that point the wires are less than two and one-half inches apart.

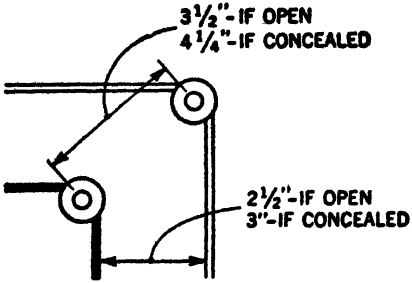
Porcelain Tubes.—Where a conductor passes through a timber or other combustible material, run it through a porcelain tube such as shown in fig. 5,245. Ordinary tubes are available in 3-, 4- and 6-inch lengths, and require a five-eighths inch hole in the timber. The holes should be bored in the approximate center of the timber, at a slight angle so that the tube will not tend to fall out of its hole from vibrations of the building. Holes for tubes may be bored with an ordinary brace and bit. For those who have a great deal of work, the power boring machine will be a good investment. It permits boring holes in ceilings up to 10 feet high through 360° of angles in any plane, putting this type of work on a production basis. Holes can be

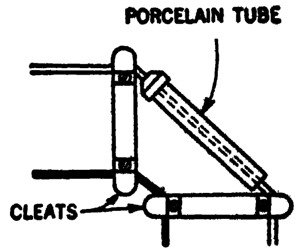


FIGS. 5,233 to 5,235.—Various types of single wire glazed cleats used in open wiring installations.



FIGS. 5,236 to 5,241.—Various types of two- and three-wire cleats and method of support. By the use of cleats instead of knobs, wires of a circuit are held at the correct distance apart.





FIGS. 5,242 and 5,243.—Methods of approved spacing when wiring with knobs and cleats respectively.

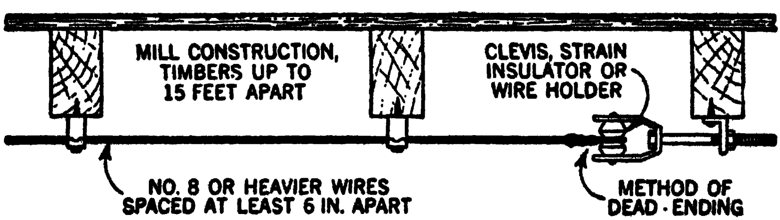


FIG. 5,244.—Method of dead-ending heavy conductors used in open wiring. When used in mill construction, open wiring saves a great deal of material and labor.

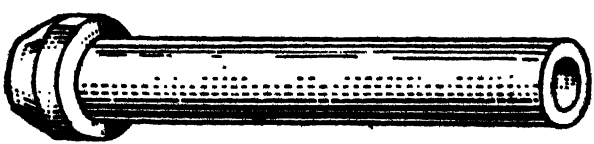
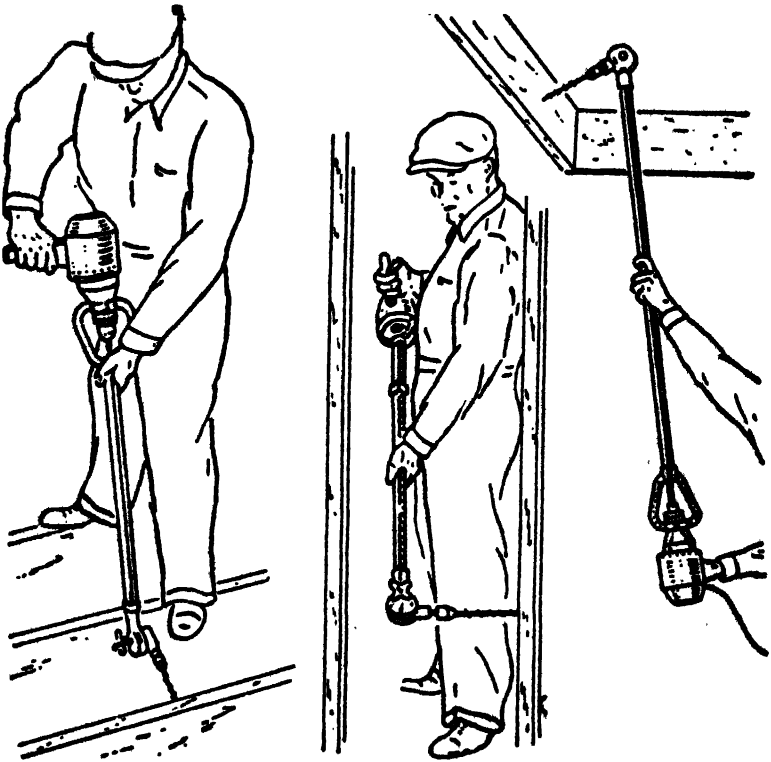


FIG. 5,245.—Typical porcelain tube; millions of these are used to protect wire conductors from mechanical or other damage which would result if no tubes were installed.

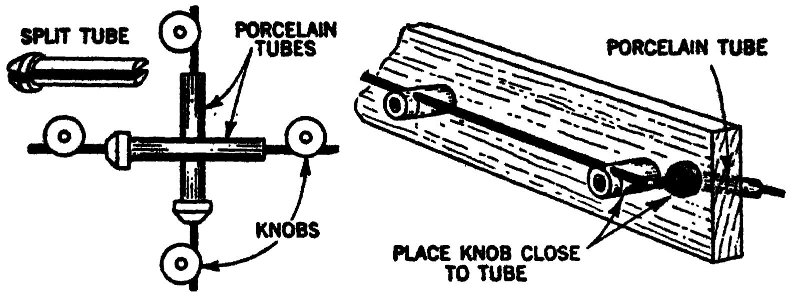
bored at a speed almost 10 times as fast as by hand. Ordinary tubes accommodate wires not heavier than No. 10; larger sizes of tubes are available for heavier wires.



FIGS. 5,246 to 5,248.—Showing method of drilling holes quickly and efficiently through wooden walls, floors or beams. This is a motor-operated tool which will save a great deal of labor, particularly in large installations where a great number of holes are needed for wiring.

Tubes are commonly used for protecting wires crossing each other, as shown in fig. 5,250. Note also the construction of fig. 5,251. A knob should be used close to the point where a

wire emerges from a tube and goes onward at a sharp angle, this at the same time taking the strain off the tube, and properly spacing the wire away from the timber.



FIGS. 5,249 to 5,251.—Methods of using split tubes over wires where they cross. Split tubes are held together with tape. Figs. 5,251 illustrates the necessity for installing a knob close to the porcelain tube if wire is to follow the timber.

Vertical Wire Runs.—Where wires must run through floors or other horizontal obstructions, a porcelain tube must naturally be used for each wire. In concealed work, another three-inch tube must be used on top of the first one. This should be clear from fig. 5,252. The purpose of this extra tube is to prevent accumulations of dust, shavings, plaster and so on, inside the wall, from coming into contact with the wires.

Separation from Metal and Other Conductors.—Open wires must be separated at least two inches from metallic conduit, piping or other conducting material, or from exposed lighting power or signal conductors, etc. If this distance cannot be maintained, a porcelain tube or other approved tubing material should be used as a wire protection. Be sure to anchor this protective material so that it cannot slip out of place. The simplest way is to provide an extra knob at each end, as illustrated in fig. 5,253.

If possible, run wires over rather than under the conducting material, so that if there be any dripping of condensed moisture, it will not fall on the wires.

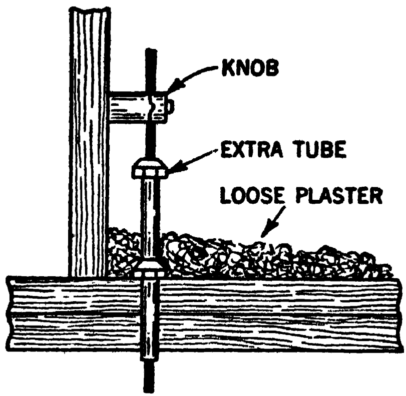
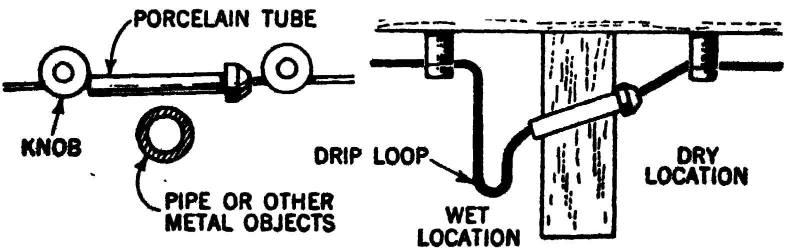


FIG. 5,252.—Wire installation when running through floors and other obstructions.



FIGS. 5,253 and 5,254.—Showing method of wiring when conductor passes in close proximity to pipes or other metal objects. Fig. 5,254 shows method of wiring when conductor passes from a dry into a wet location.

Wet Locations.—When wires run from a dry into a wet location, a drip loop must be formed in the wire, as shown in fig. 5,254, so that condensed moisture will drip off. The porcelain tube must slant so that condensed moisture will flow back into the wet location.

Taps.—In making a tap, insulators must be placed on each side of the tap and the insulation removed from the wires and soldered and taped, as shown in fig. 5,255. The wires must

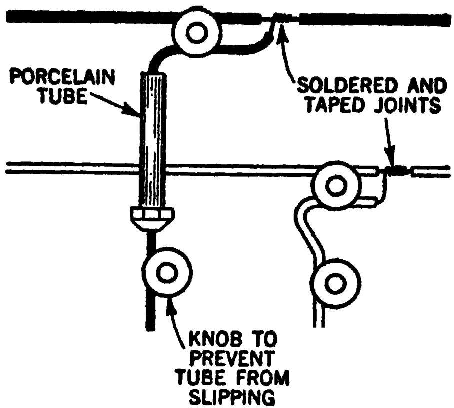
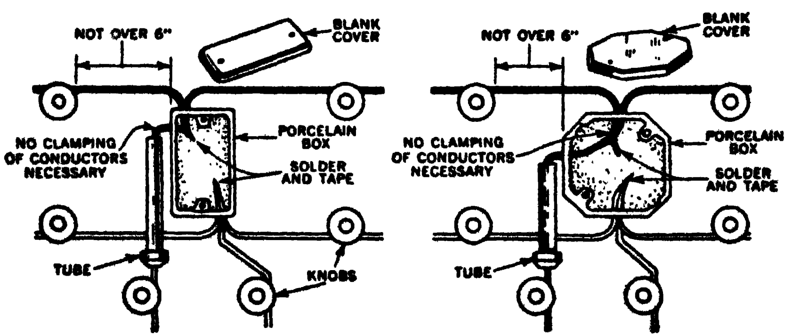


FIG. 5,255.—Ordinary tap construction used in an open wiring system. Note how the stress is removed from the tap by means of tie wires securely fastening the wires to knobs. When porcelain tubes are installed in the manner shown, they efficiently protect both wires at each crossing.



FIGS. 5,256 and 5,257.—Methods of tap construction in outlet or switch box. In making a tap, insulators must be placed on each side of the box so as to prevent stress on the wire joints.

be supported within six inches. Note the porcelain tube over the top wire where it crossed the main wire. A preferable method is to use porcelain outlet or switch box with blank cover, as illustrated in figs. 5,256 and 5,257.

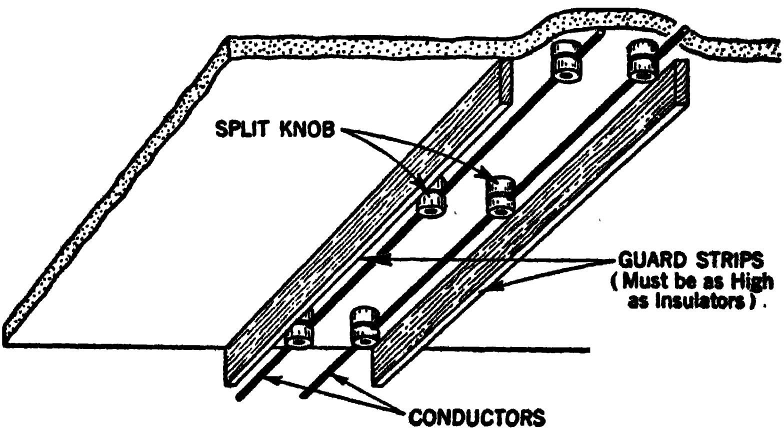


Fig. 5,258.—Guard strips to protect open wiring on low beams or ceilings when the conductors are located at a distance of less than seven feet from the floor.

Protection Against Mechanical Injury.—Where open conductors cross ceiling joists and wall studs, and are exposed to mechanical injury, they shall be protected by one of the following methods. Conductors within seven feet from the floor shall be considered exposed to mechanical injury:

1. By guard strips not less than seven-eighth inch in thickness and at least as high as the insulating supports, placed on each side of and close to the wiring

2. By a substantial running board at least one-half inch thick back of the conductors with side protections. Running boards shall extend at least one inch outside the conductors, but not more than two inches and the protecting sides shall be at least two inches high and at least seven-eighth inch thick.

3. By boxing made as shown and furnished with cover kept at least one inch away from the conductors within. Where protecting vertical conductors on side walls the boxing shall be closed at the top and the holes through which the conductors pass shall be bushed.

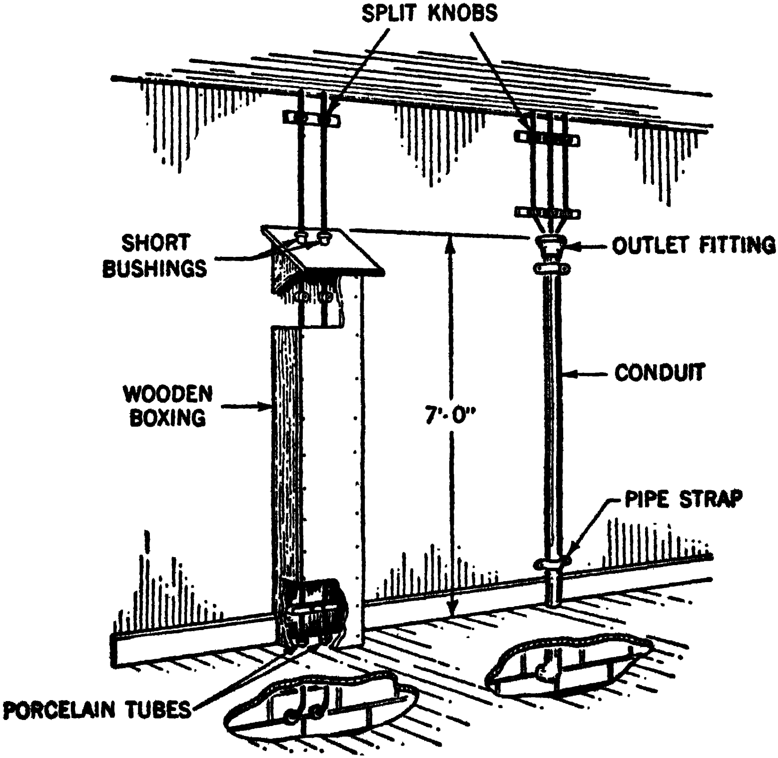
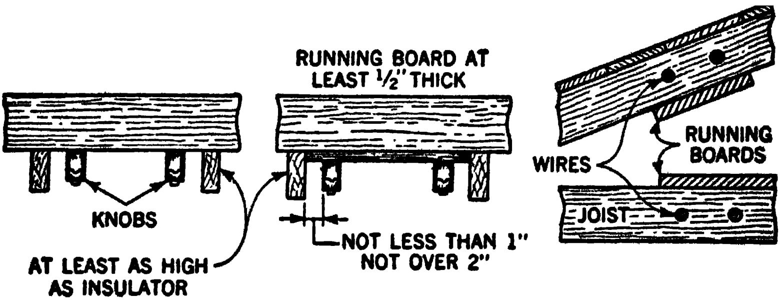


FIG. 5,259.—Method of protecting wires when they pass through floors.

4. By conduit, in which case the rules for conduit shall be followed, or by metal piping in which case the conductors shall be encased in continuous lengths of approved flexible tubing. The conductors passing through conduit or piping shall be so grouped that current in both directions is approximately equal.

Wiring in Attics and Roof Spaces.—Conductors in unfinished attics and roof spaces shall comply with the following:

1. Conductors in unfinished attics and roo. paces shall be run through or on the sides of joists, studs and rafters, except .. attics and roof spaces having head room at all points of less than three feet in buildings completed before the wiring is installed.



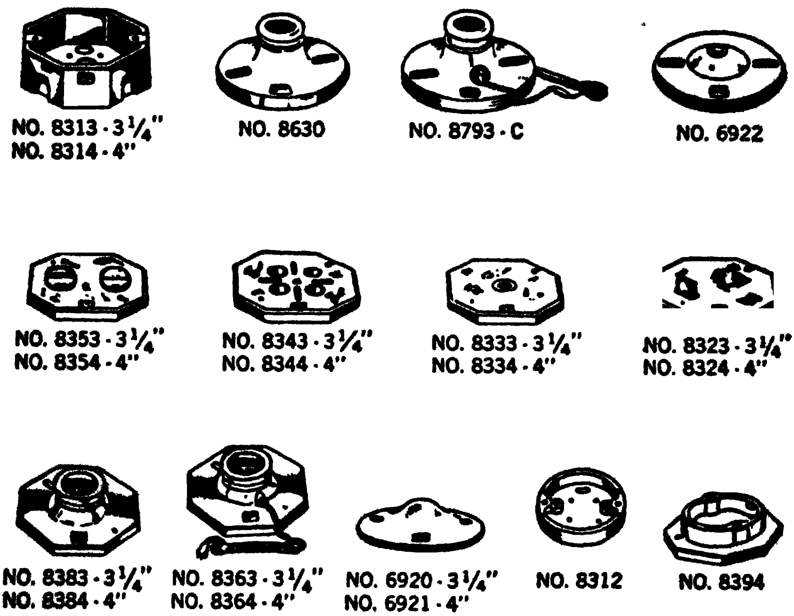
FIGS. 5,260 to 5,262.—Methods of protecting wires when running through attics and roof

2. If conductors in accessible unfinished attics or roof spaces reached by stairway or permanent ladder are run through bored holes in floor joists or through bored holes in studs or rafters within seven feet of the floor or floor joists, such conductors shall be protected by substantial running boards extending at least one inch on each side of the conductors and securely fastened in place.

3. If carried along the sides of rafters, studs or floor joists, neither running boards nor guard strips will be required.

Type of Outlet Boxes.—Porcelain boxes are available in the usual three and one-half and four-inch octagonal outlet type, as well as flush and surface switch type, with covers to fit, as shown in figs. 5,263A to 5,263M. The knockouts are thin sections of porcelain, well protected against accidental removal, yet easily and quickly removed with screw driver or similar tool.

Four of the knockouts are large enough for cable or rubber-covered wire inside of loom. Each box also has two smaller knockouts to take rubber-covered wire directly. Being on the opposite sides of the box, they automatically keep two wires entering the box far enough apart and far enough from the surface, so that no additional protective covering is required.



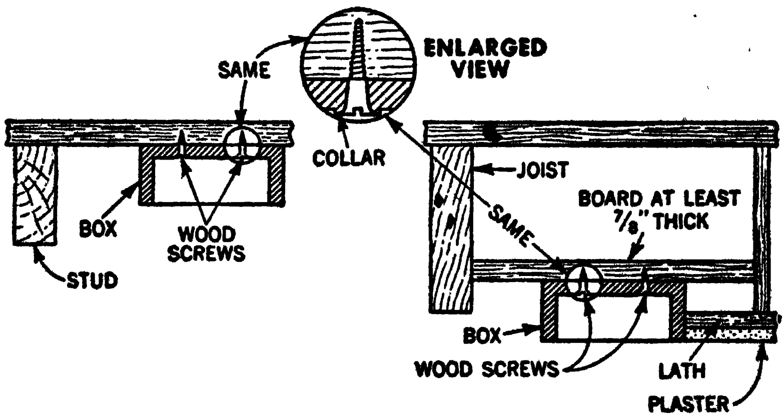
FIGS. 5,263A to 5,263M.—Octagon porcelain outlet boxes and covers.

Mounting Porcelain Outlet Boxes.—Porcelain outlet boxes are mounted readily and easily, the method of mounting depending on the location and the material on hand.

In open work, the box can frequently be mounted on a ceiling or wall, using No. 9 woodscrews one inch long for the

purpose. Mounting on a board spaced between the two joists is very similar, as noted in figs. 5,264 and 5,265.

The usual "deep" offset hanger is also in common use for mounting these boxes between joists, the box being attached to the hanger with flat head stove bolts, with head inside of



FIGS. 5,264 and 5,265.—The simplest method of supporting outlet boxes is to mount them on the timber directly.

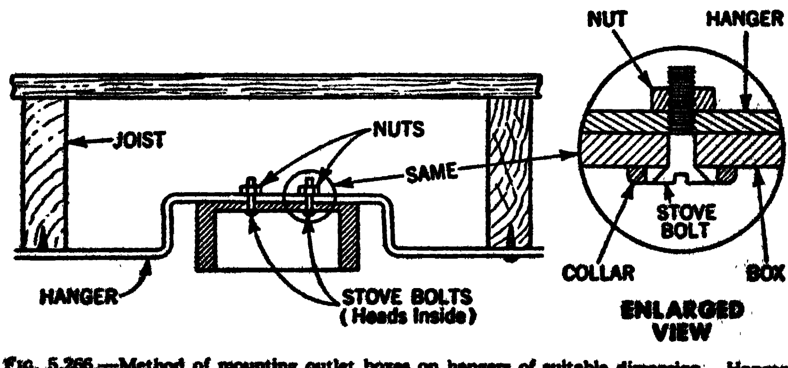
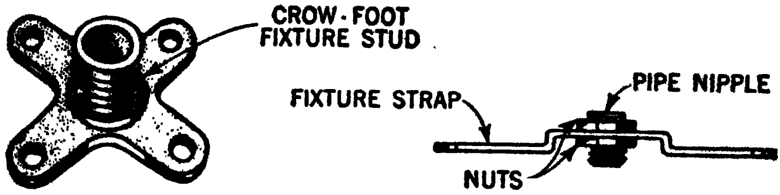
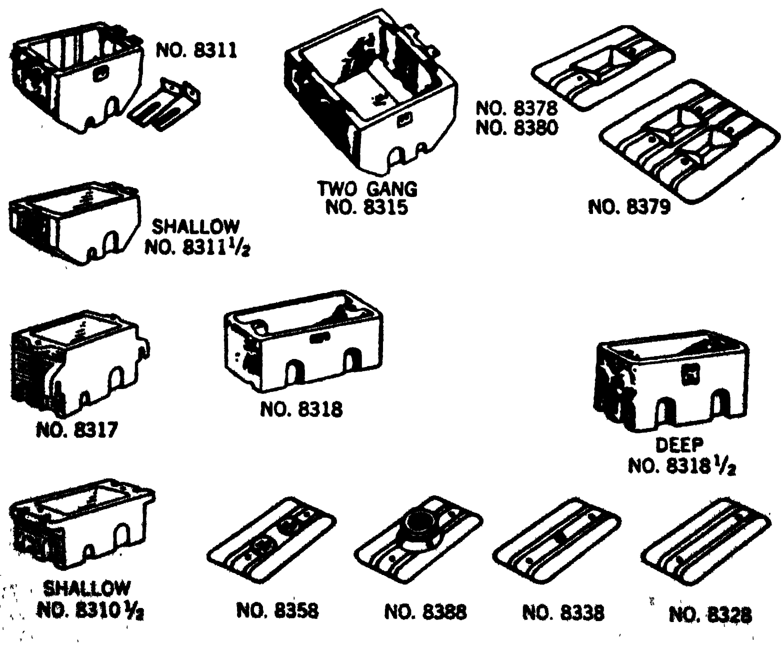


FIG. 5,266.—Method of mounting outlet boxes on hangers of suitable dimension. Hangers such as shown provide an excellent support for the box and will, in addition, facilitate its proper placement.

box, as shown in fig. 5,266, or by means of the standard combination fixture stud.



FIGS. 5,267 and 5,268.—Showing additional methods of fixture support.



FIGS. 5,269A to 5,269M.—Various switch and receptacle outlet boxes and covers.

The crow-foot shown in fig. 5,267 may be attached to porcelain boxes by means of flathead stove bolts, or if the box be mounted on timber, by wood screws long enough to reach the bottom of the box and into the timber. Either method is acceptable. If stove bolts be used, they should be inserted from back of the box with the nut inside box to assure isolating the stud from electrical contact outside the box.

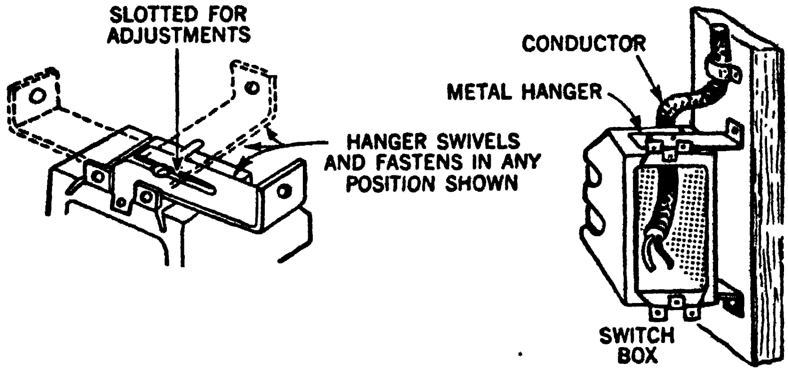
Fig. 5,268 shows the use of a fixture strap and pipe nipple to support the fixture. Fixture straps usually have slotted mounting holes for mounting on either three and one-quarter or four-inch boxes.

Switch Boxes.—Porcelain switch boxes are available in both the flush- and surface-mounted types as shown in fig. 5,269A to 5,269M.

Porcelain switch boxes are especially advantageous from a safety standpoint, because with many brands of switches, receptacles, and similar devices, there is very little room between the terminals and the sides of the box. Particularly if the device is not mounted perfectly straight in the box, the terminal may come perilously close to the side of the box. Then there is danger that the bare wire, where it attaches to the terminal, will touch the wall of the box; a dangerous situation with a box of conducting material, but harmless and safe with porcelain because the box itself is a perfect insulator.

Mounting Switch Boxes.—Surface type boxes are mounted as described for outlet boxes. The flush type may be mounted in several ways. The ears on the flush type are adjustable, so that the front edge of the box can always be brought flush with the surface of the plaster. Incidentally, plaster forms a firm bond with porcelain boxes, making a particularly neat job.

Each flush switch box is provided with a pair of slotted metal hangers which makes their mounting simple. The two hangers are attached to the ears on the end of each box, as shown in fig. 5,270; the hangers are then nailed to an upright stud as shown in fig. 5,271. The ears are still adjustable so that the front edge will line up with the plaster.

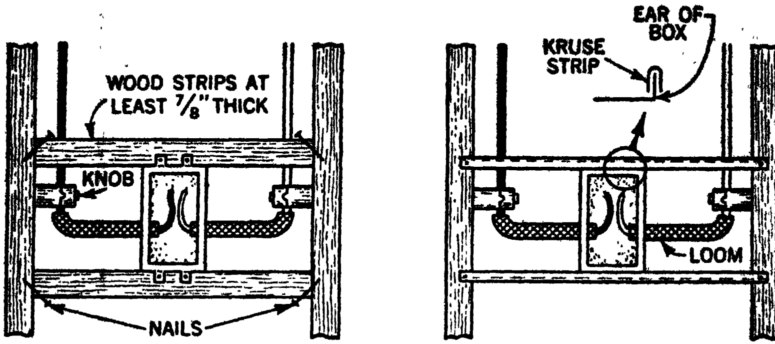


Figs. 5,270 and 5,271.—Methods of supporting switch boxes under various conditions of wiring.

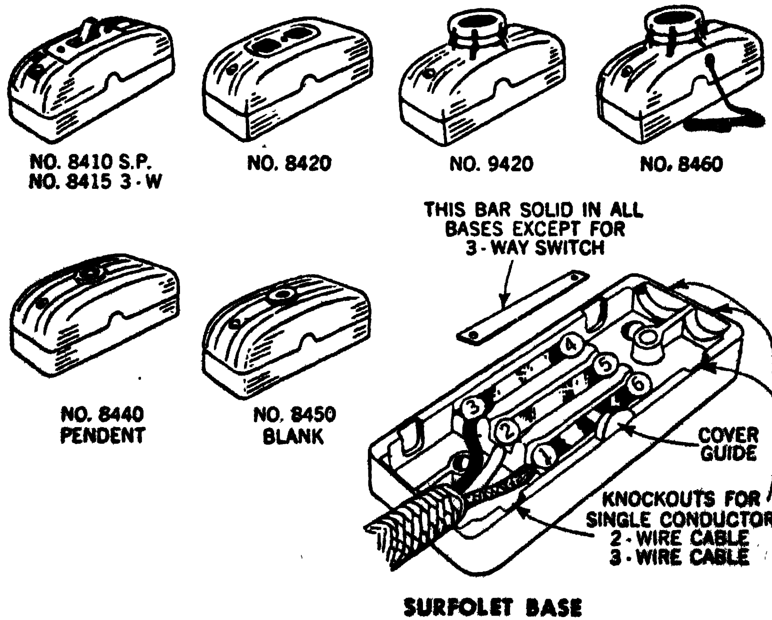
The box may also be mounted directly on wooden strips as in fig. 5,272 or by the aid of the well known metal "Kruse strips" of fig. 5,273. These strips are folded pieces of metal with a U section in which the ears of the box rest.

Surfolet Wiring.—A Surfolet is an Underwriter's-approved combination outlet box and wiring device such as a switch, or plug-in receptacle, or screw-shell receptacle.

Surfolets are used in attics, cottages, warehouses, farm buildings, etc., or in fact any location where surface wiring is acceptable. They combine all the advantages of a porcelain-protected wiring system with the additional advantages of quick, easy installation.



Figs. 5,272 and 5,273.—Method of mounting switch boxes between wall studs or other supports in wooden frame construction.



Figs. 5,274A to 5,274G.—Various surfolets outlet fixtures with base connections.

In addition, they eliminate all soldering and taping, which operations are frequently carelessly handled. Surfolets are used with knob and tube or non-metallic sheathed cable wiring. Connectors are not required but the conductors must be anchored within eight inches of each device.

Only six different Surfolets are needed for any wiring job, as shown in figs. 5,274A to 5,274G. They all use the same base, except the three-way switch shown in fig. 5,274G. Note the "hump" on one side of the base; this assures correct installation of all covers.

Knockouts are removed by tapping with a screwdriver or similar tool from the outside. At each end of the base are two knockouts, that is, a small one for a 2-wire cable and a large one for a 3-wire cable. Each end contains in addition two still smaller knockouts for rubber-covered wires.

It will be noted that the terminals are marked from 1 to 6. A brass jumper connects 3 with 4, a whiteish jumper connects 2 with 5, solid brass jumper connects 1 with 6 in all devices except the three-way switch. The three-way switch has a split brass bar as shown in fig. 5,274G.

The various devices built into the covers make contact with these jumpers through flat spring fingers, when the cover is installed on the base.

The general connection scheme works as follows:

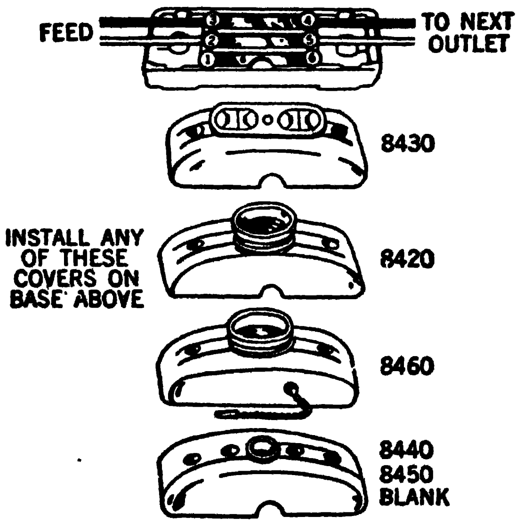
1. The load is automatically connected to terminals two and three when cover is screwed to the base.

2. Closing a single pole switch connects terminal one to terminal three.

3. When a three-way switch is installed, and with the handle of the switch in one position, terminal one is connected to terminal six.

In the other position of the switch handle, terminal one is connected to terminal three.

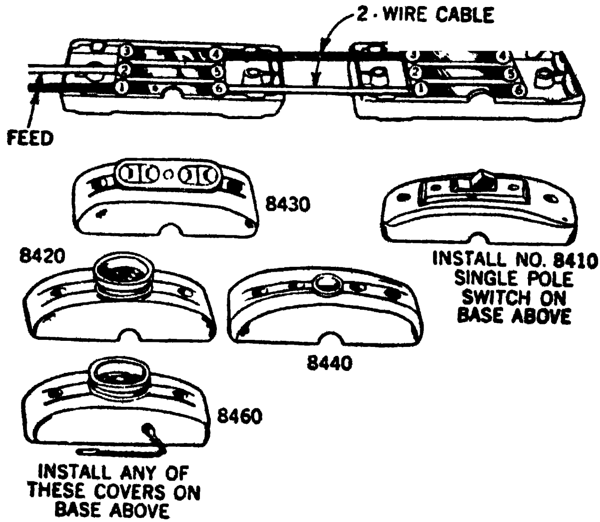
Installation of Surfolets is relatively simple, requiring no special explanation. Fig. 5,274G shows the proper method of attaching cable to base. Note that the separate wires of the cable are brought around the boss surrounding the screwhole for the mounting screw. Practical installation diagrams for various common circuits are shown in figs. 5,275A to 5,279C.



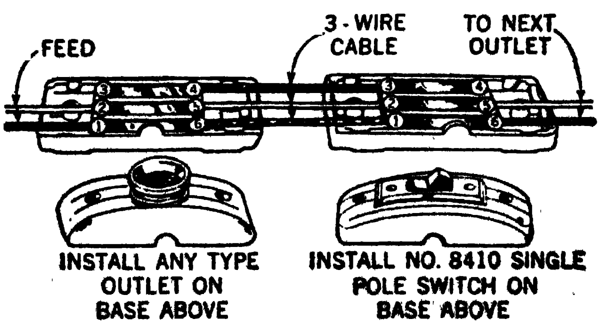
FIGS. 5,275A to 5,275E.—Showing a simple surfolet 2-wire outlet with suitable bases.

Simple Outlet.—A simple two-wire outlet is installed by placing the base in the desired location, attaching the white neutral wire to terminal No. 2, which is of whiteish color. The black or "hot wire" is similarly connected to terminal No. 3, as shown in fig. 5,275A. The installation is completed by providing the proper style cover which is secured to the base in the usual manner.

Switched Outlet.—Fig. 5,276A shows the outlet of fig. 5,275A, now controlled by a switch. In this installation, the white neutral wire is attached to terminal No. 2 as before, but the black or "hot wire" is attached to terminal No. 1 of the

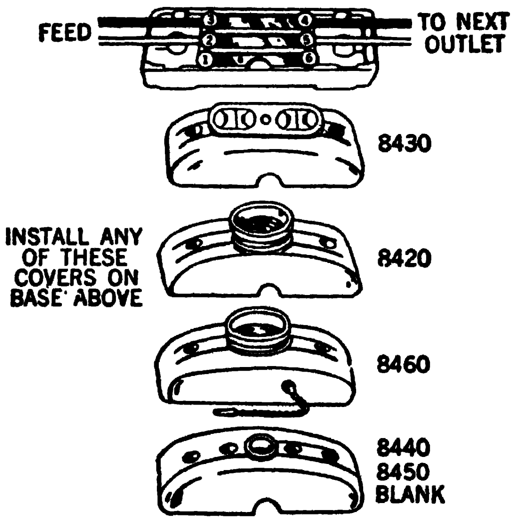


FIGS. 5,276A to 5,276F.—Simple surfolet 2-wire outlet with switch in circuit.



FIGS. 5,277A to 5,277C.—Same as fig 5,276A, except feeding on to another outlet.

Installation of Surfolets is relatively simple, requiring no special explanation. Fig. 5,274G shows the proper method of attaching cable to base. Note that the separate wires of the cable are brought around the boss surrounding the screwhole for the mounting screw. Practical installation diagrams for various common circuits are shown in figs. 5,275A to 5,279C.



FIGS. 5,275A to 5,275E.—Showing a simple surfolet 2-wire outlet with suitable

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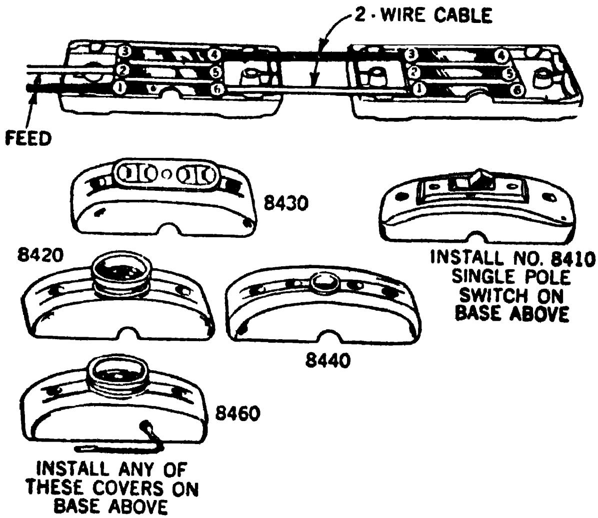
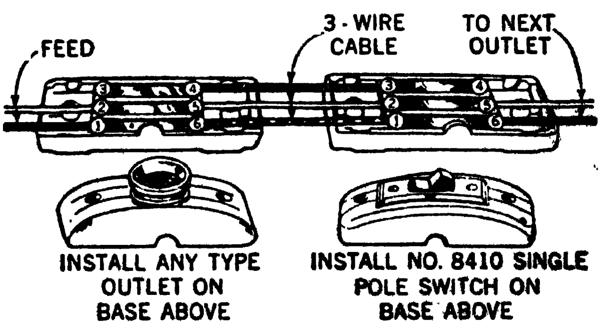
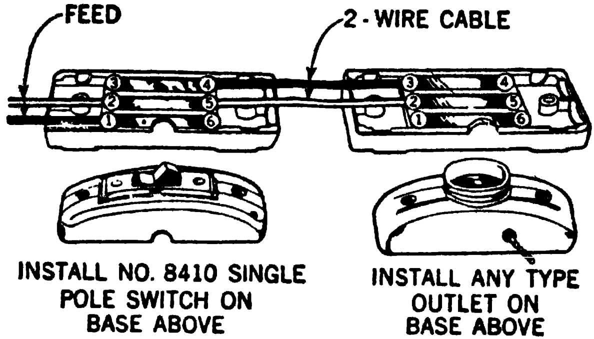


FIGS. 5,276A to 5,276F.—Simple surfolet 2-wire outlet with switch in circuit.

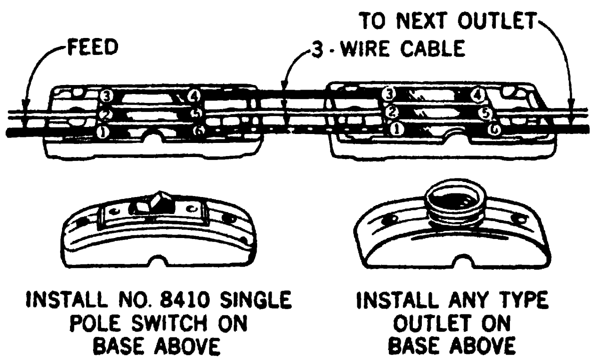


FIGS. 5,277A to 5,277C.—Same as fig. 5,276A, except feeding on to another outlet.

first base instead of terminal No. 3 as in the case of the unswitched outlet. A piece of two-wire conductor between the two bases completes the installation.



FIGS. 5,278A to 5,278C.—Same as fig. 5,276A, except feeding through the switch.



FIGS. 5,279A to 5,279C.—Same as fig. 5,276A, except feeding on to another outlet.

If it is desired to continue the feed beyond the switch, for additional outlets not controlled by the switch, it is merely necessary to run three-wire instead of a two-wire cable between the first two bases and continue from terminals No. 5 and No. 6 of the second base, to the new outlet as shown in fig. 5,277A.

CHAPTER 106

Wiring in Moulding

"Raceway Wiring"

The term *raceway* is now frequently used instead of moulding. By definition a moulding or raceway is *a protective covering for exposed wires.*

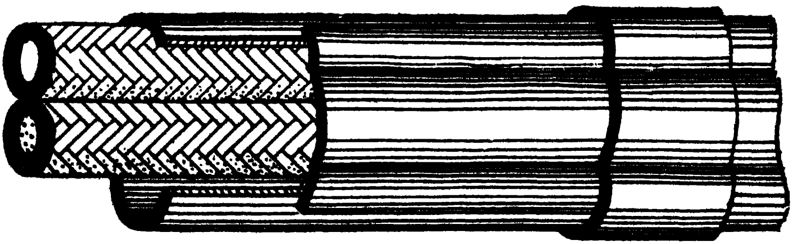


FIG. 5,284.—National small two piece moulding adapted to either *laying in* or *fishing*. This moulding may be screwed directly to the surface through the holes provided in the base or it may be secured by straps provided for the purpose.

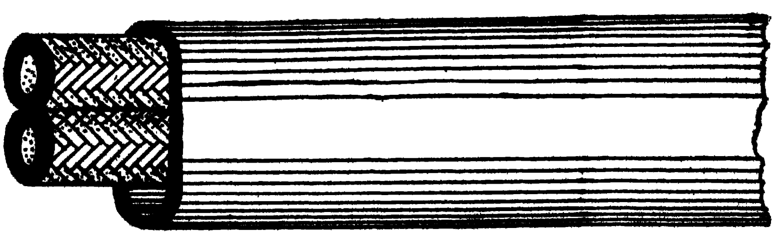


FIG. 5,285.—National two wire one piece moulding.

Mouldings may be divided into two classes with respect to the material of which they are constructed.

1. Wooden;
2. Metal.

Although the Code still permits the use of wooden moulding, it is prohibited in some cities by local ordinance and is now practically obsolete.

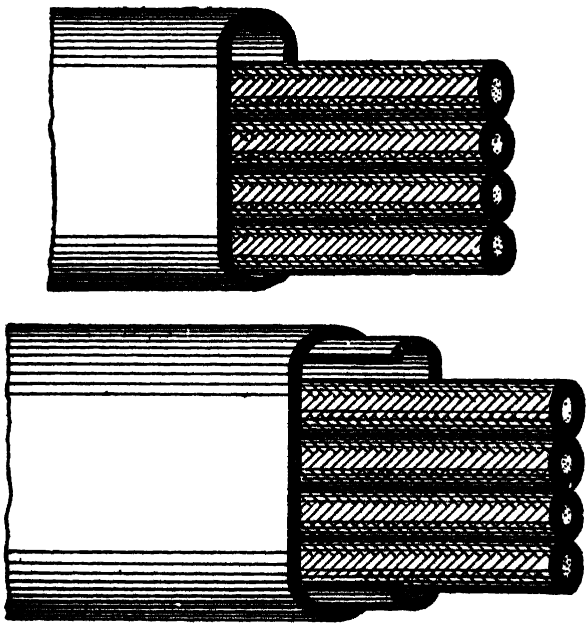


FIG. 5,286.—National four wire one piece metal moulding.
FIG. 5,287.—National four wire two piece metal moulding

Raceway wiring (either wood or metal) should never be installed in damp places, because the wires are close together and moisture easily enters a raceway.

Metal Moulding.—This kind of casing for wires, also known as *raceway*, provides a metallic box-like covering which fits

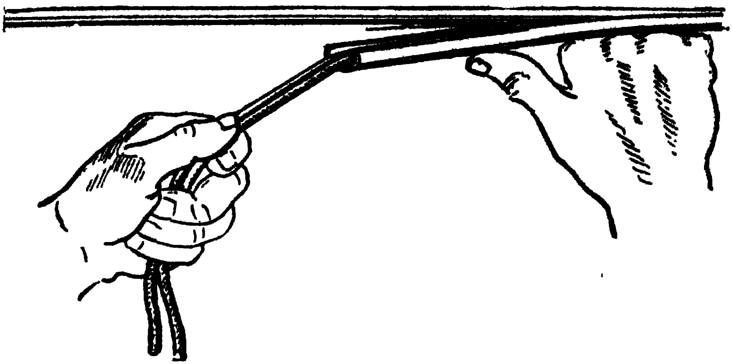


FIG. 5,288.—Method of *laying in* wires in National two piece moulding. After the wires are in place *snap* the cap over the base as shown. To perform this operation properly, place one hand under the capping, hold it at a slight angle with the base, press one end over the base, and at intervals of two or three inches, exert a steady pressure on the capping. Do not lay the capping squarely on top of the base and pound it. By the method shown the capping snaps quickly and easily over the base. Laying wires in long ceiling runs of moulding is accomplished easily in nearly the same manner as shown above, except that the wires should be guided and held in the capping by the hand which keeps it at an angle with the base

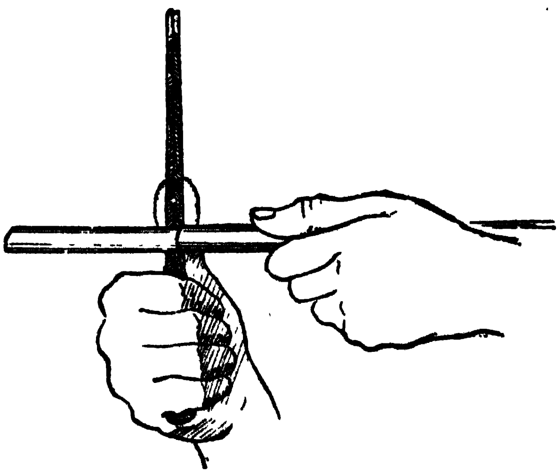
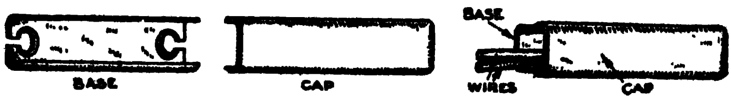


FIG. 5,289.—Method of cutting metal moulding with three cornered file. *In cutting*, use a small piece of capping for a straight edge, as shown; mark the base or capping deeply and break it off, being very careful to mark the moulding deeply on both sides.



Figs. 5,290 to 5,292.—National metal moulding; two piece or *laying in* type. The two pieces are so formed as to *snap* together, the cap over the base as in fig. 5,292.

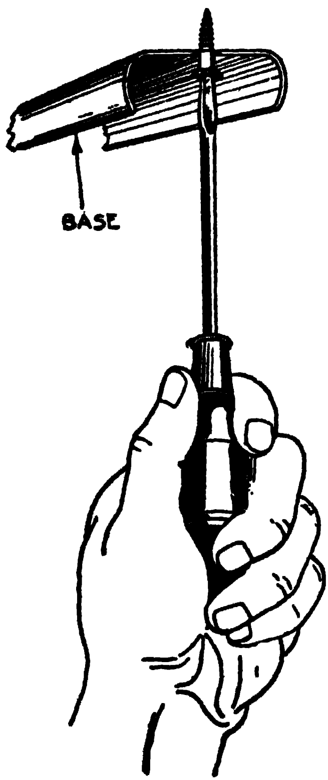


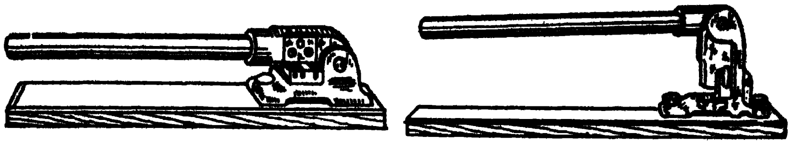
Fig. 5,293.—Method of attaching base of National two piece moulding to ceiling or wall.

snugly over the wires and protects them from injury. As compared with wooden moulding, the metal moulding takes up less room and has a better appearance. Two leading makes of metal moulding are illustrated to explain this method of wiring.

Metal mouldings are made in two types which differ greatly from each other, requiring different methods of inserting the wires as by

1. Laying in;
2. Fishing.

NOTE.—Method of r ving capping from two piece moulding. *To remove*, lift the capping from the base at one end by prying with a screw driver, then slide the blade of the screw driver the full length between the capping and base.



FIGS. 5,294 amd 5,295.—Shear and punch for cutting and punching metal moulding.

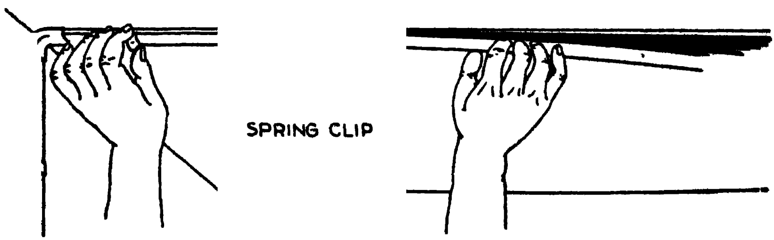
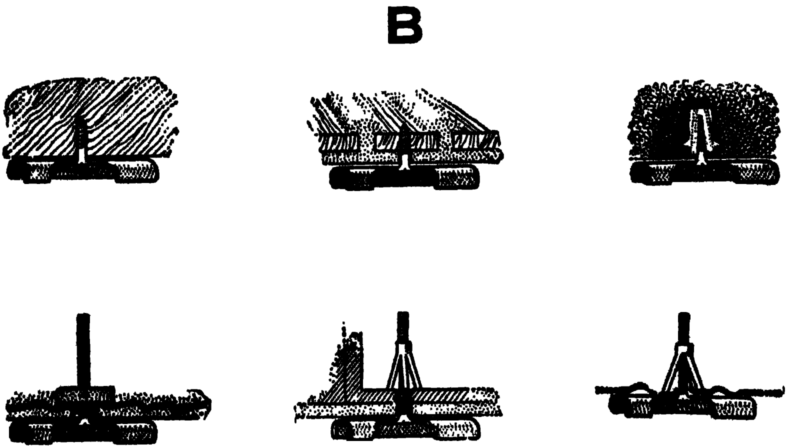


FIG. 5,296.—Method of "capping" ceiling run of National two piece moulding.



FIGS. 5,297 to 5,302.—Methods of supporting National metal moulding. A, *on wood*, use flat head screw; B, plaster on wood lath, use flat head wood screw; C, brick or concrete, use Crawlplug or lead shield; D, plaster or metal lath, use National toggle; E, hollow tile, use National spring head toggle; F, on metal ceiling, use National spring head toggle.

National Metal Moulding.—This moulding is made in two types, each in two wire and four wire sizes, giving the workman

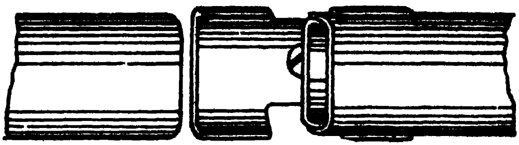
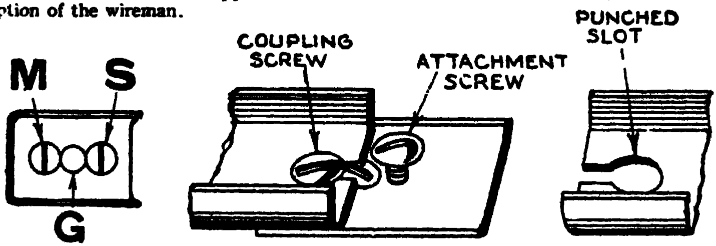


FIG. 5,303.—Method of coupling National metal moulding with support fitting. The joint is covered by a joint cap fitting. In this method of coupling, lengths of four-wire moulding can be snapped into the coupling only with cap and base assembled, and the wires fished through. The two wire moulding can be snapped into a special coupling fitting assembled, or the base alone can be supported; which allows the wires to be laid in, or fished at the option of the wireman.



FIGS. 5,304 to 5,306.—Base coupling fitting and method of coupling. This is for four wire moulding only. *To couple,* first punch key hole slots in the moulding base with hand punch. These slots fit around the two screws **M** and **S**, fig. 5,304. The center hole **G**, is for fastening the base to ceiling or wall The base coupling can only be used when the base and cap are installed separately.

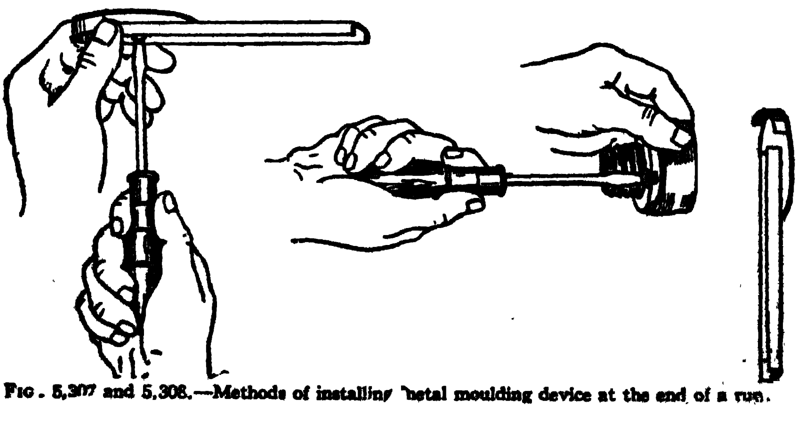


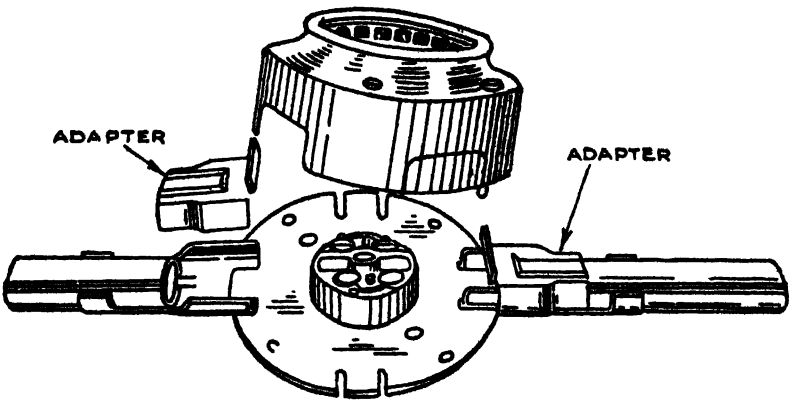
FIG. 5,307 and 5,308.—Methods of installing metal moulding device at the end of a run.

a choice of *laying in* or *fishing* wires. The laying in form consists of a *base* and *capping* or cover made of steel, as shown in figs. 5,290 and 5,291, and assembled as in fig. 5,292.

In the installation of the moulding, there are two methods of cutting the moulding—by hack saw or by a special shear.

If a hack saw be used, select only a fine toothed flexible hack saw with tempered edges; coarse toothed blades crack and break on moulding.

When cutting moulding with a hack saw it is not necessary to cut all the way into moulding, but only just nick the moulding, so if it be given

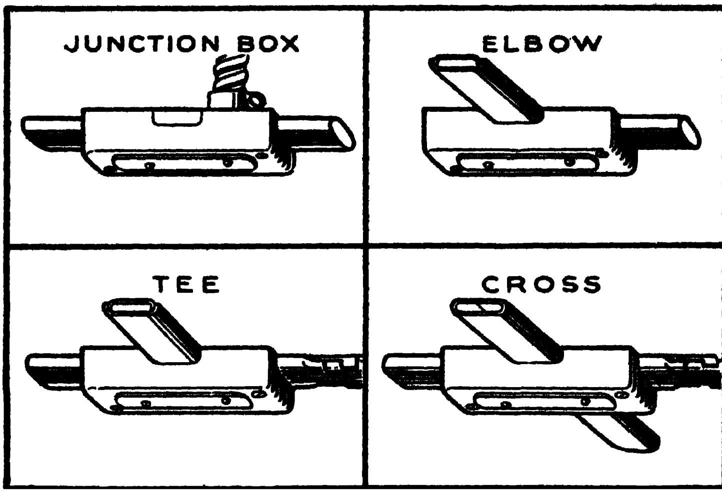


FIGS. 5,309 to 5,311.—Method of connecting National two wire one or two piece mouldings into devices. The adapter takes these mouldings into all device twistouts. The large end of the adapter connects to all device bases by the push fit method (shown in figs. 5,334 to 5,338 for four wire moulding) and the two wire moulding snaps into the small end of it.

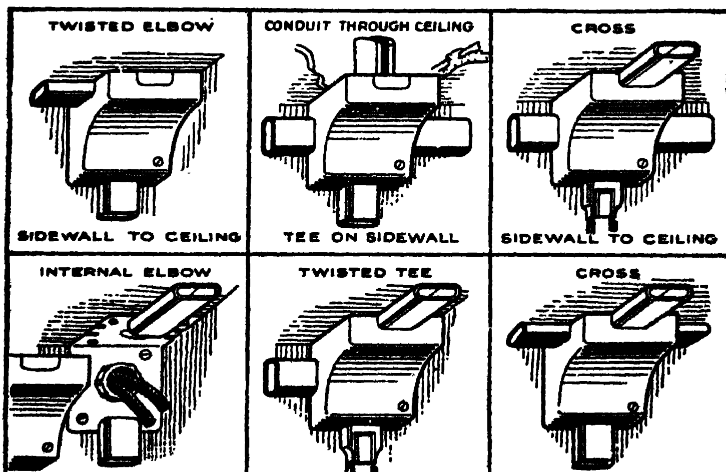
a slight up and down motion it will break apart. Files also may be used, the three cornered being the best. Holes must be punched in the base for screws, these can be made with a special punch or may be drilled by a twist drill in a brace or breast drill.

Bending.—The base and capping must be assembled and bent as one piece of moulding. The moulding is quite soft and is easily bent over the knee or the edge of a table; hickeys may be obtained for this purpose.

Avoid crossing the wires in the capping as this causes capping to bulge and short circuit. The moulding is coupled together by means of special couplings



FIGS. 5,312 to 5,315.—Use of National utility box for junctions, branches and taps.



FIGS. 5,316 to 5,321.—Use of National cover box in surface installi

In running around beams the base only is bent by cutting a 90° V with a hack saw at the bend. Both internal and external bends may be made by means of these notches. The capping is then laid in place after which the corners are covered over with special elbow covers.

The two piece moulding allows ready access to the wiring for extensions or inspection.

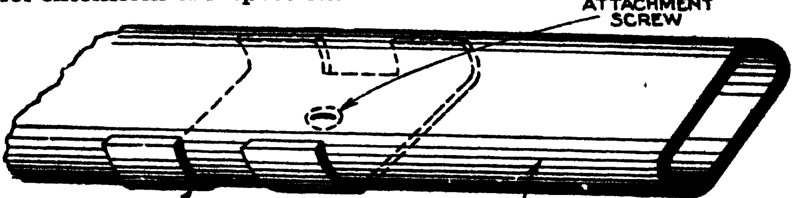
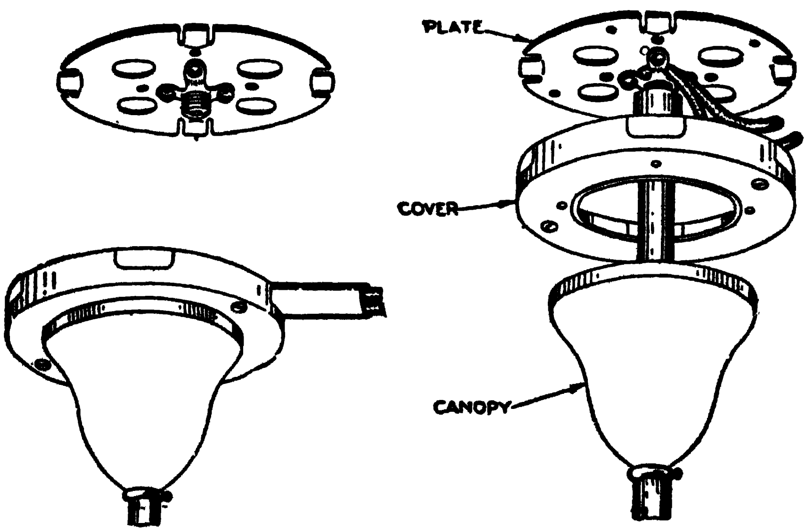


FIG. 5,322.—Method of supporting National *one* piece metal moulding with a spring clip fitting. First the fitting is attached to the ceiling or wall with a screw, then the run of moulding is "snapped" into the fitting.



FIGS. 5,323 to 5,325.—Method of connecting National moulding to fixture outlets and canopies, through canopy bases and fixture studs. Fig. 5,323, plate; fig. 5,324, fixture in place; fig. 5,325, cover and canopy ready for fastening.

It also permits addition of tunneled base devices to completed installa tions, and makes it possible to assemble a number of these devices on a length of moulding, as a unit, to be later placed in show windows, etc.

The smallest size of National two piece moulding, shown in fig. 5,284, permits either *laying in* the wires then capping it, or *fishing* wires through the assembled moulding.

One piece mouldings consist of oval metal tubes in which ample room is provided for fishing wires.

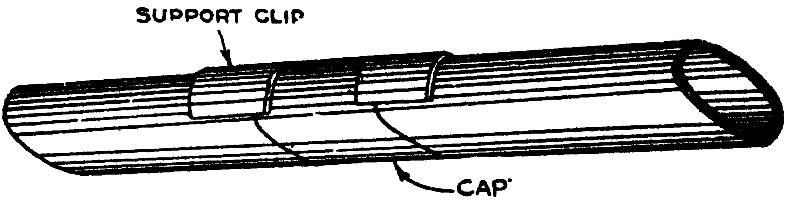


FIG. 5,326.—Method of coupling lengths of National one piece moulding with support fitting and coupling cap.

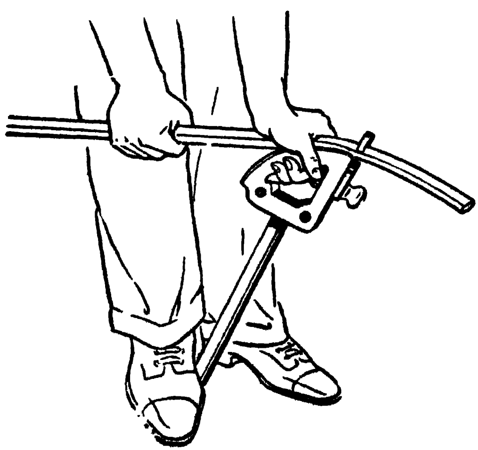
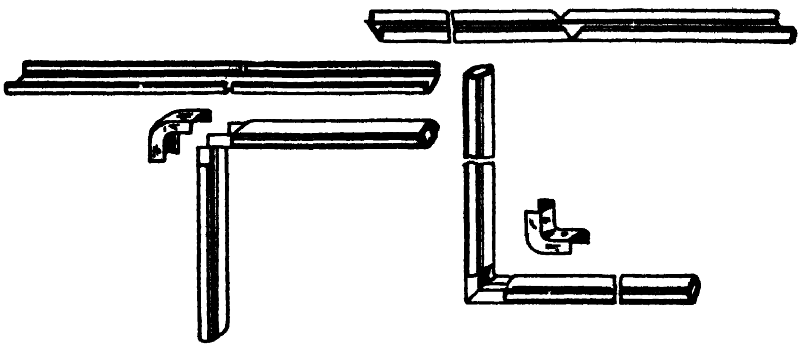


FIG. 5,327.—Correct use of bending tool in bending National moulding. *In bending,* the force should be applied near the bending tool; and when a screw hole comes within the length of the two wire two piece moulding to be bent, the pressure should not be exerted too suddenly.

A method of supporting one piece moulding with a spring clip fitting is shown in fig. 5,322. Lengths of one piece moulding are coupled as shown in fig. 5,326.

The two wire, one piece and four wire, two piece mouldings can be bent to an arc of 4 in. radius with the bending tool shown in fig. 5,327.



FIGS. 5,328 to 5,330.—Method of making external 90° angle by notching.

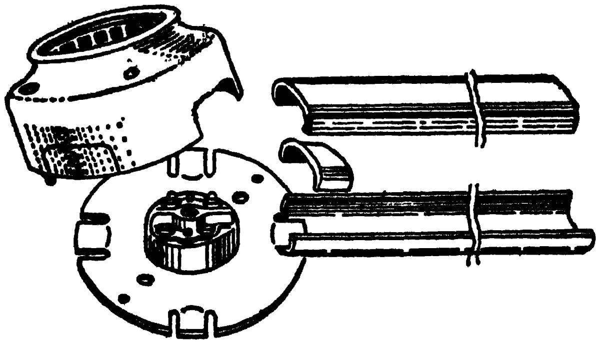
FIGS. 5,331 to 5,333.—Method of making internal 90° angle by notching.

These mouldings should be bent assembled to give the capping and base the same curve. It is not advisable to attempt bending the four wire one piece moulding.

90° as angles are made in four wire two piece moulding by notching. To make a 90° external angle by notching, saw a vertical slot down through the sides to the flat part of the base as in fig. 5,328, then, bend it around the angle as in fig. 5,330, and snap on a 90° external angle elbow cap, fig. 5,329.

To make a 90° internal angle by notching cut a V shaped notch from the sides of the base with a hacksaw or three cornered file, as in fig. 5,331, then bend the moulding into the angle, as in fig. 5,333, and snap on a 90° internal angle elbow cap, fig. 5,332.

There is a multiplicity of fittings for metal mouldings and no attempt is made to show all of them, but from the explanations and illustrations given the manipulation of the fittings must be apparent.



FIGS. 5,334 to 5,338.—Method of connecting National four wire, one and two piece mouldings into devices. These mouldings slide under the tongues in all device bases. Before finally placing the device cover, the twistout must be removed, as shown. The bushing is required when connecting into devices, to protect the wires from abrasion. As shown it is inserted in the capping.

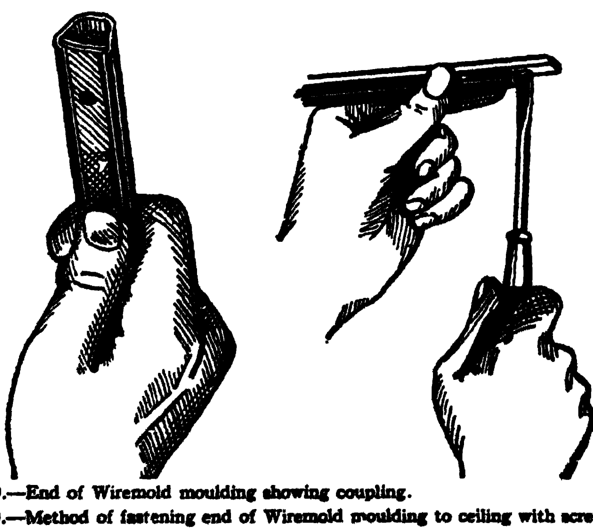
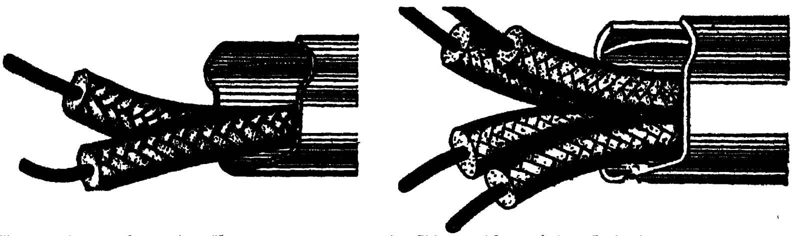
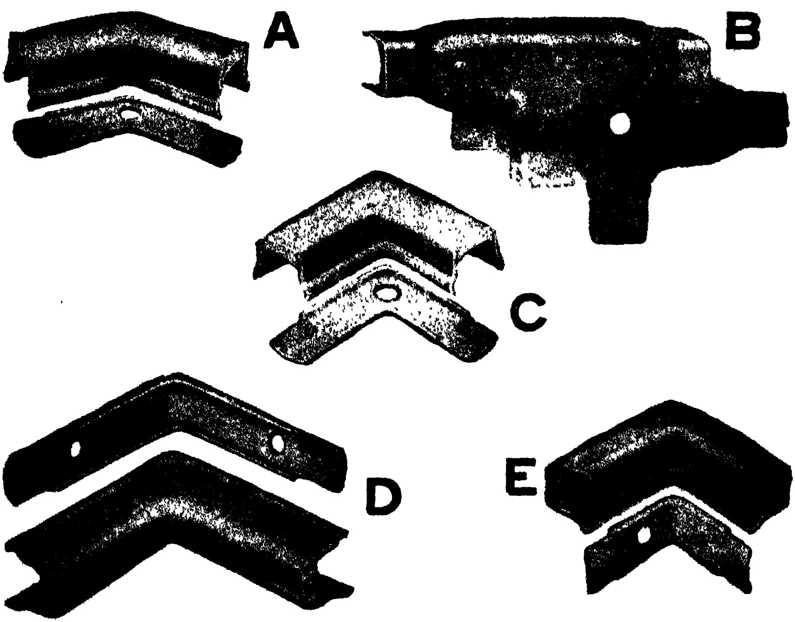


FIG. 5,339.—End of Wiremold moulding showing coupling.
FIG. 5'340.—Method of fastening end of Wiremold moulding to ceiling with screw.

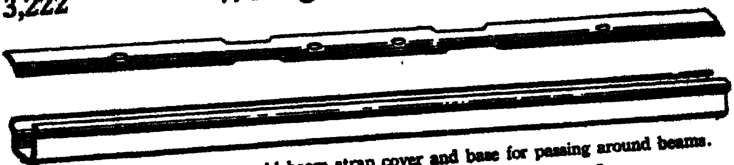
Wiremold Metal Moulding.—This type of moulding has no removable cap and is installed like wrought pipe except that



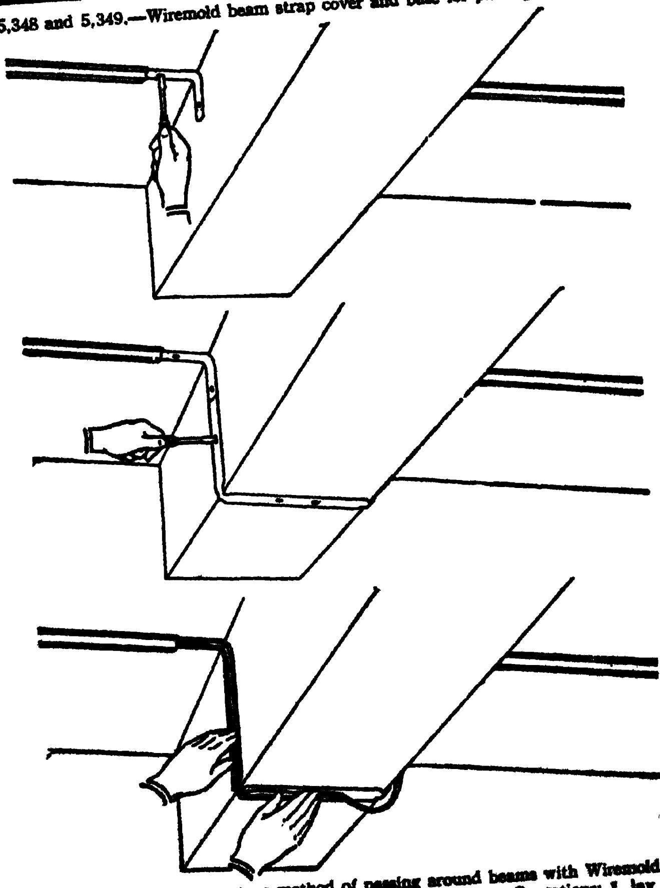
FIGS. 5,341 and 5,342.—Two wire and four wire Wiremold conduit. It is designed for use in large installations requiring circuits of 2 or 4 wires, such as factories, railroad buildings, lofts, warehouses, department stores, office buildings, hospitals, school buildings and the like. Is also adapted for signal and call systems. It comes in 10 ft. lengths.



FIGS. 5,343 to 5,347.—Wiremold angle fittings. A, 45° flat elbow; B, tee; C, 90° flat elbow; D, internal 90° elbow; E, external 90° elbow.



FIGS. 5,348 and 5,349.—Wiremold beam strap cover and base for passing around beams.

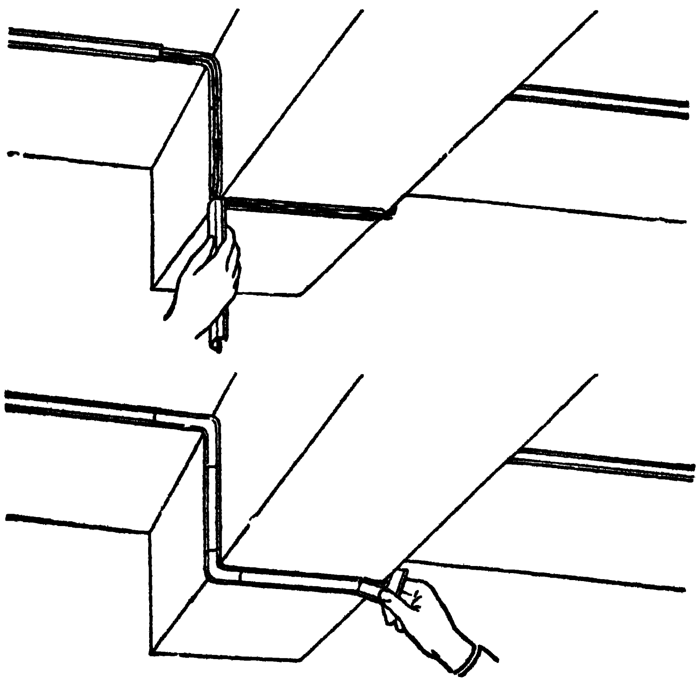


FIGS. 5,350 to 5,354.—Beam strap method of passing around beams with Wiremold wiring. The strap and cover used are shown in fig. 5,348 and 5,349. Operations: 1, lay internal

a "slip joint" is used for coupling lengths and for coupling with fittings rather than the threaded coupling required for pipe.

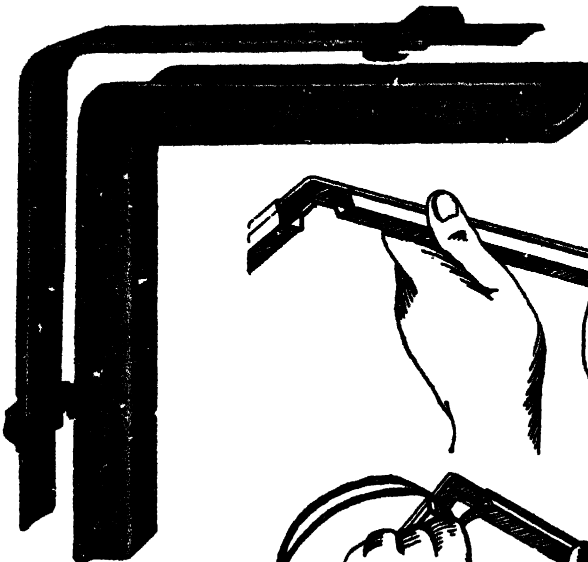
Fig. 5,341 shows the appearance of the moulding. Each length is furnished with a coupling as in fig. 5,339. To connect lengths of Wiremold conduit, first push the coupling part way out to the end of Wiremold conduit and fasten the coupling to the ceiling or wall as shown in fig. 5,340.

Slip the next length of the moulding over the edges of the coupling as in fig. 5,360, thus providing a concealed coupling as well as support at the

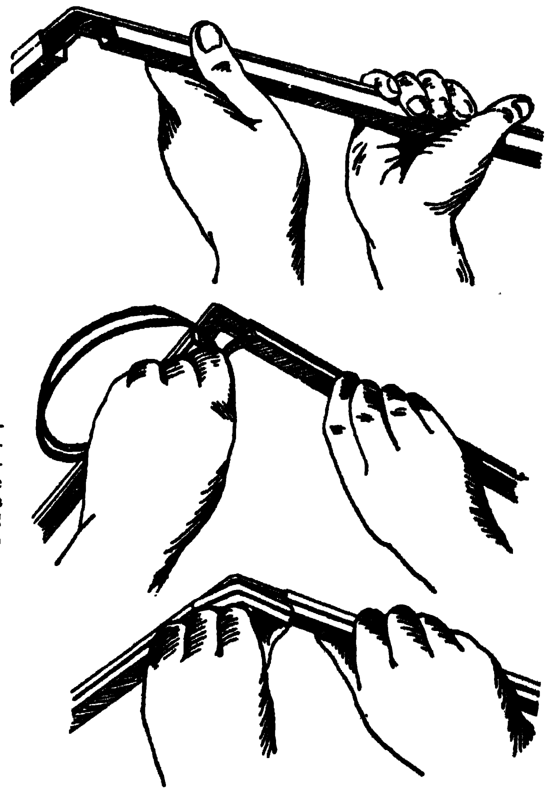


Figs. 5,350 to 5.354.—*Text continued.*

elbow base in usual way, as in fig. 5,350; *2*, install screw-on beam strap base around beam, as in fig. 5,351; *3*, lay wires against base pieces, as in fig. 5,352; *4*, cut slide-on capping and slip on over base, as in fig. 5,353; *5*, snap on elbow covers, as in fig. 5,354



FIGS. 5,355 and 5,356.—Wiremold long 90° external elbow. All elbows have removable covers and serve as pull boxes because wires cannot be fished around them with their covers in place.



FIGS. 5,357 to 5,359.—Method of making a 90° turn with a Wiremold flat 90° elbow. First assemble coupling tongues in base plate as in fig. 5,357, being careful that the coupling tongue goes *outside* the moulding base. After fastening the base plate to the wall with wood screw or toggle bolt, push in or fish in the wires as in fig. 5,358. Finally, snap on the elbow cover, breaking off the crescent shaped twistouts in the ends for use with the four wire moulding. Do not put covers on any of these fittings until wiring is completed.

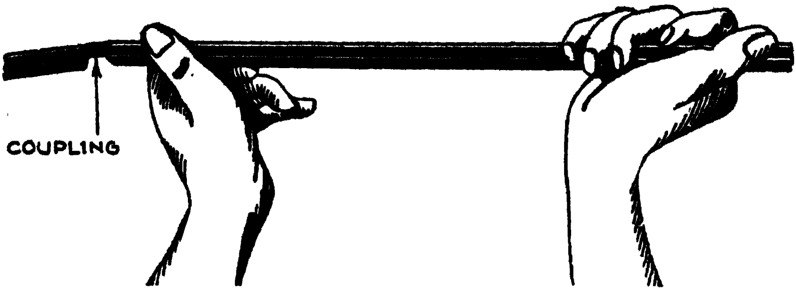
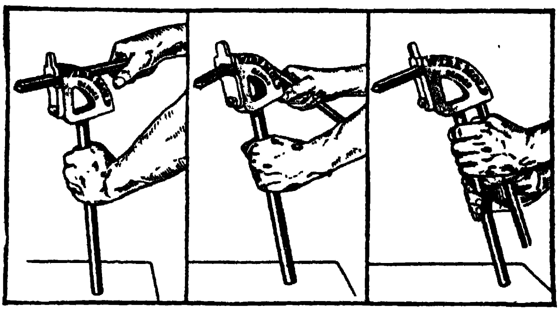


FIG. 5,360.—Slip joint method of coupling Wiremold moulding.



FIGS. 5,361 to 5,363.—Wiremold bender and its use. To make an internal bend or offset with Wiremold bender, put Wiremold conduit into the tool as shown in fig. 5,361, apply pressure close to the tool as in fig. 5,362, and finish bend as in fig. 5,363. External bends or offsets are made in same manner by simply reversing position of the moulding in the bender.

FIG. 5,364.—Method of making bends or offsets in the middle of a length of Wiremold moulding with bender on floor using foot support and applying pressure close to tool as indicated by arrow in ci

end of each length. Between ends, the moulding is supported by clips.

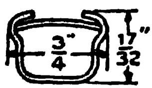
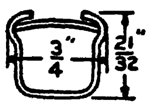
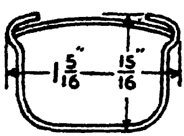
RACEWAY SYSTEMS	WIRE SIZE	WIRE CAPACITY	
	AWG	Type R or RH	Type T or RU
200 	14	3	3
	12	2	3
500 	14	5	6
	12	4	6 (Compares with ¾" conduit)
	10	2	4
	8	—	2
700 	14	7	8
	12	6	8 (Compares with 1" conduit)
	10	3	6
	8	2	3
1000 	14	10	10
	12	10	10
	10	6	8 (Compares with 1½" conduit)
	8	5	8
	6	4	5
1500 	14	4	8
	12	4	6
	10	—	4
	8	—	4

FIG. 5,365.—Wiremold reference chart.

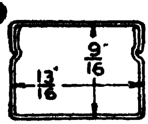
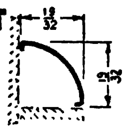
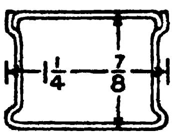
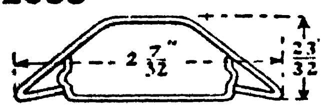
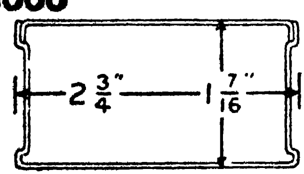
		With Devices	Without Devices	With Devices	Without Devices
1900 	14	3	3	3	3
	12	3	3	3	3
1900 T 	5-PAIR TELEPHONE WIRES				
2100 	14	2127 -10 2127G- 8 2127S -10 2140 - 8	10	2127 -10 2127G- 8 2127S -10 2140 -10	10
	12	2127 - 8 2127G- 4 2127S - 8 2140 - 6	10	2127 -10 2127G- 8 2127S -10 2140 - 8	10
	10	—	10	—	10
	8	—	6	—	8
	6	—	4	—	5
2600 	TWO 26-PAIR TELEPHONE CABLES				
3000 	14	10	10	10	10
	12	10	10	10	10
	10	10	10	10	10
	8	8	10	10	10
	6	6	8	8	8

FIG. 5,366.—Wiremold reference chart.

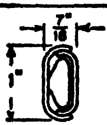
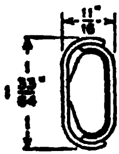
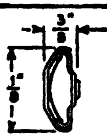
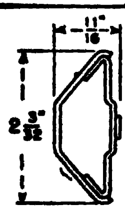
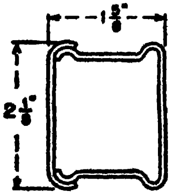
Type of raceway	Wire size gage No.	Number of wires Types R, RH	 Types T, RU
 No. 111	14 12	3 2	3 3
 No. 333	14 12 10 8 6	7 6 3 2	9 8 6 3 2
 No. 888	14 12 10 8 6	10 10 9 7 4	10 10 10 10 5
 No. 711-A	14 12 10 8	7 4 2 2	9 5 4 3
 No. 733-A	14 12 10 8 6	10 10 10 7 4	10 10 10 10 6
 No. 1700	14 12 10 8 6	All types of wire, with or without devices 10 10 10 10 10	

FIG. 5,367.—Wiremold reference chart.

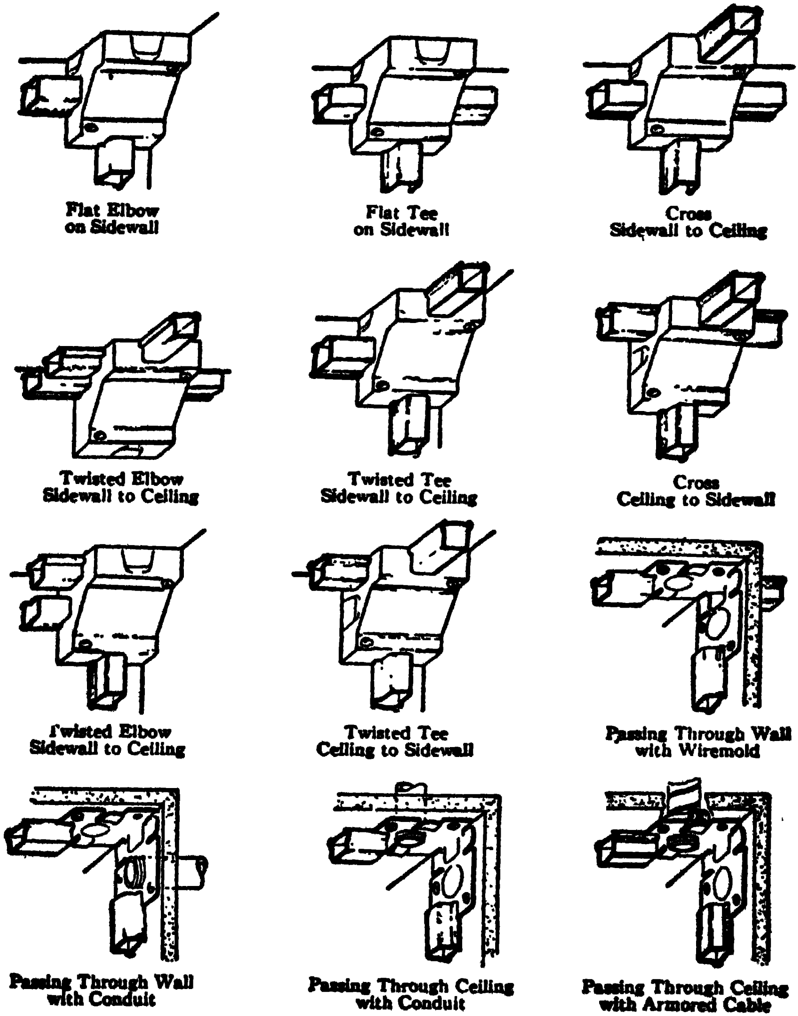
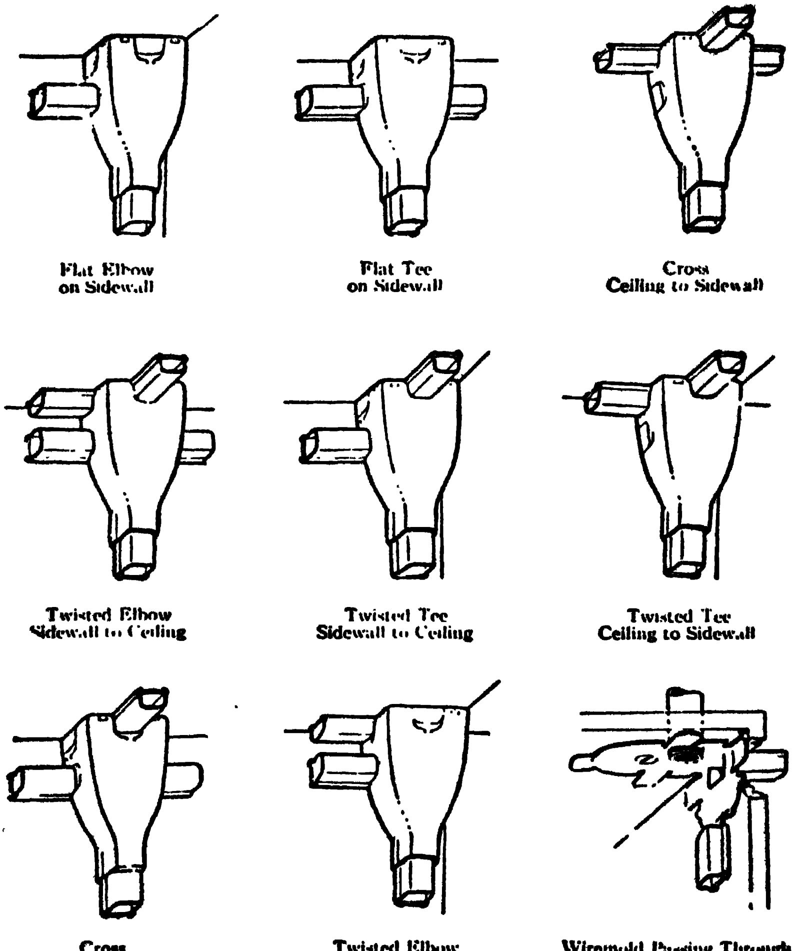


FIG. 5,368.—Illustrating some of the many uses of Wiremold No. 5719 corner box.



Flat Elbow on Sidewall

Flat Tee on Sidewall

Cross Ceiling to Sidewall

Twisted Elbow Sidewall to Ceiling

Twisted Tee Sidewall to Ceiling

Twisted Tee Ceiling to Sidewall

Cross Sidewall to Ceiling

Twisted Elbow Sidewall to Ceiling

Wiremold Passing Through Wall and to Conduit Through Ceiling

FIG. 5,369.—Various wiring services for Wiremold No. 5719A corner box.

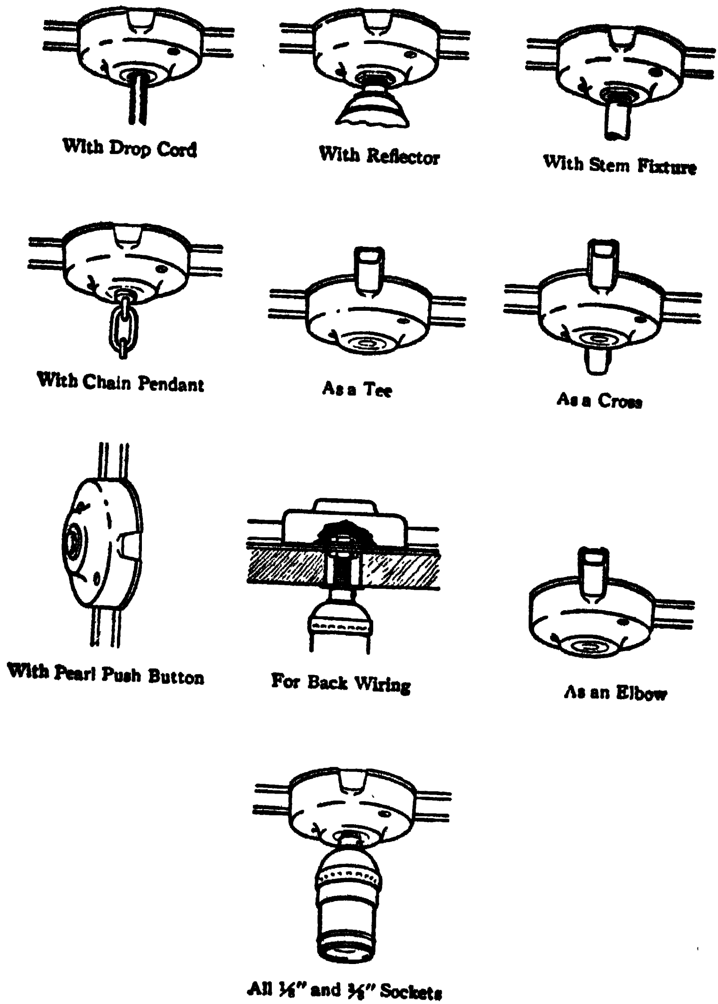


FIG. 5,370.—Illustrating various applications for Wiremold No. 5721 round utility box.

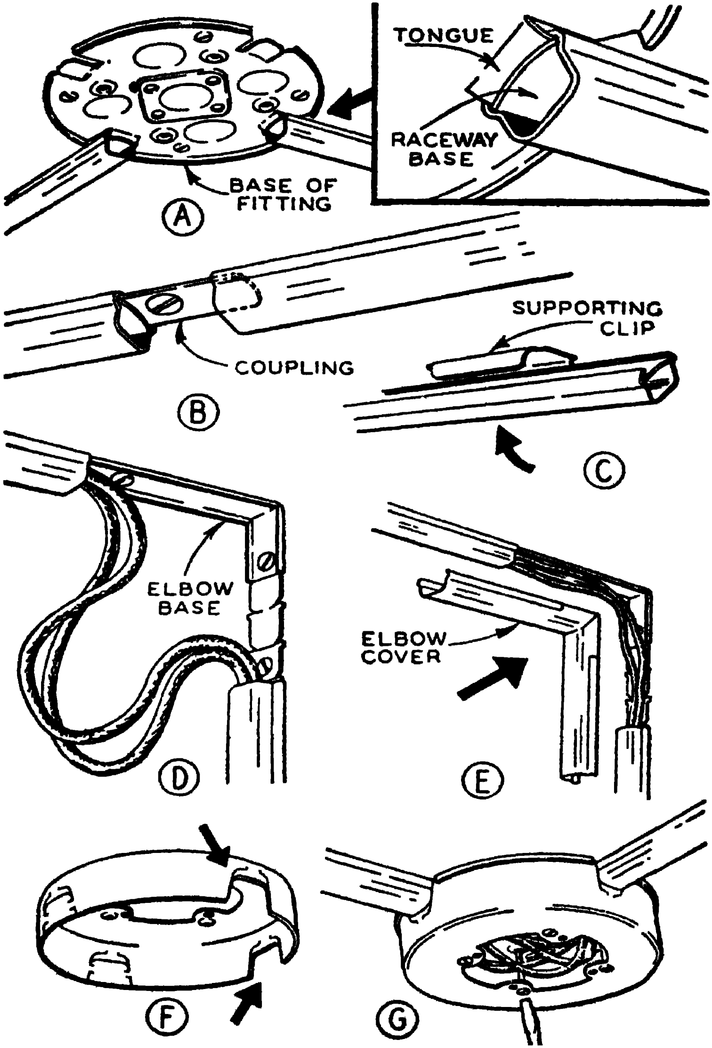


FIG. 5,871.—Showing typical installation of a Wiremold surface raceway system.

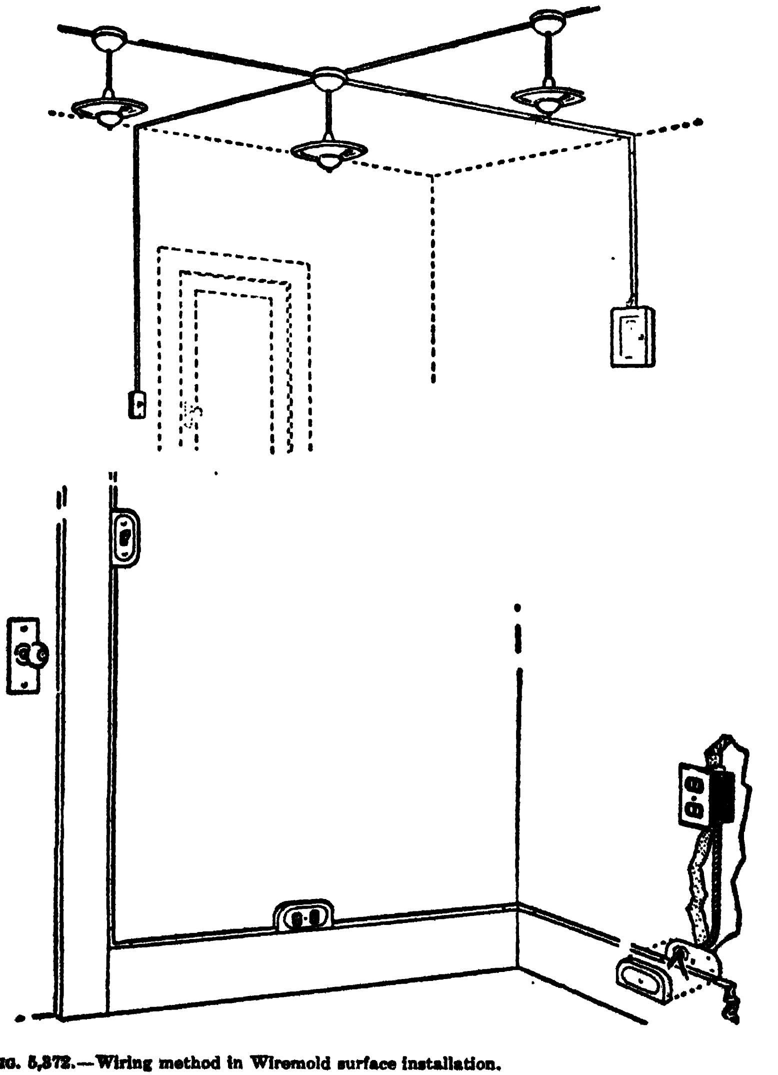


FIG. 5,372.—Wiring method in Wiremold surface installation.

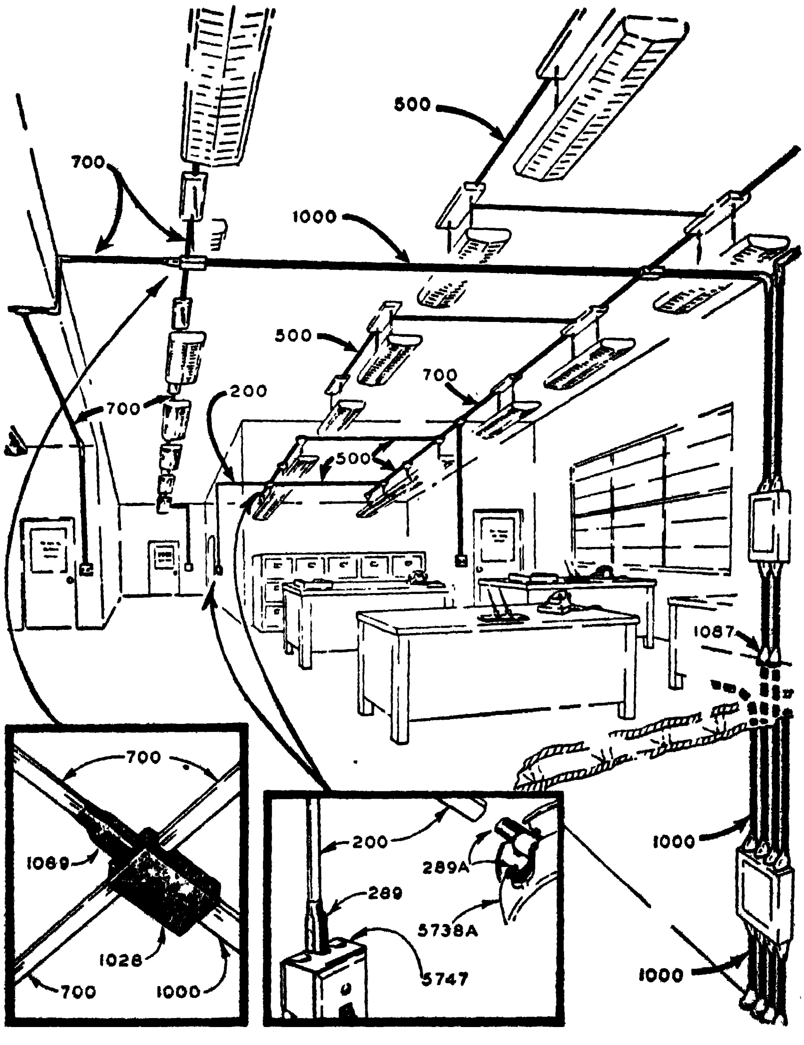


Fig. 5,373.—Wiremold surface raceway wiring in typical office installation.

TEST QUESTIONS

1. *What other term is used in place of mouldings?*
2. *What is the best kind of moulding to use?*
3. *How many wires are carried in metal moulding?*
4. *Give method of laying in wires in two piece moulding*
5. *How is metal moulding cut?*
6. *Describe the method of fastening moulding to ceilings or walls.*
7. *How are two lengths of moulding joined together?*
8. *Describe a special tool for cutting moulding.*
9. *Give various methods of supporting mouldings.*
10. *Describe the fittings used for coupling mouldings.*
11. *What kind of hack saw should be used in cutting mouldings?*
12. *Describe the method of bending moulding.*
13. *How is moulding run around beams?*
14. *What is the advantage of the two piece moulding?*
15. *Describe method of connecting moulding to fixture outlets.*
16. *What is the method of coupling one piece moulding?*
17. *How is the special bending tool used?*
18. *How are 90° angles made?*
19. *Describe some of the fittings used.*

20. *Give the method of connecting four wire, one and two piece mouldings into devices.*
21. *How does "wiremold" metal moulding differ from other mouldings?*
22. *Describe the various wiremould fittings.*
23. *How is wiremould run around beams?*

CHAPTER 107

Wiring with Armored Cable

Armored cable consists of *a cable in which the conductor or conductors are covered by a specially wound steel casing.*

In the manufacture of armored cable the steel strip which forms the armor is rolled and galvanized; the conductors are twisted and covered and finally wrapped with the armor strip.

The shape given to this strip is the result of careful scientific study and test. It is this shape which gives strength and flexibility. On account of its flexibility armored cable is an ideal form of wiring for those types of installation where there are many turns and short runs. It is a very economical method of wiring finished buildings, as it can readily be installed without defacing walls or decorations.

Armored cable is manufactured with single or double strip armor but the single strip is the type generally used.

Single strip armored cable is formed of one continuous strip, with the edges rolled over to fit together; the convolutions are rounded.

Double strip armored cable has armor formed of two channel shaped metal strips, wound so that their upturned edges face and engage each other, giving an armor of double thickness and great flexibility.

It has flat convolutions which make fishing of wires and pulling through holes easy. The sectional view, fig. 5,381, shows the construction of armored cable.

While wiring with armored cable has not the advantage of the conduit systems, namely, that the wires can be withdrawn and new wires inserted without disturbing the building in any way whatever, yet it has many of the advantages of the flex-

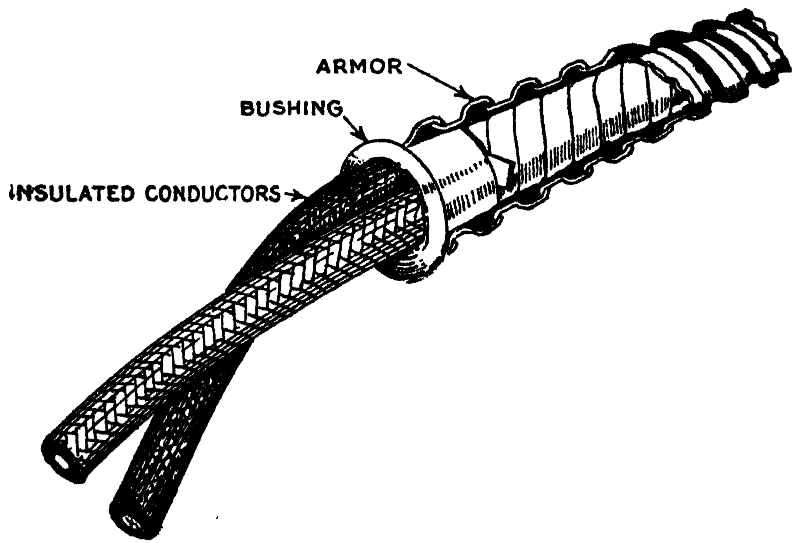


FIG. 5,381.—National armored cable showing insulation and construction of the armor.

ible steel conduit, and it has some additional advantages of its own.

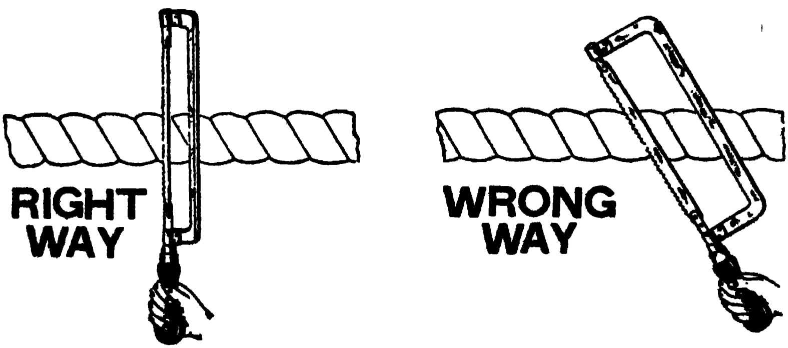
For instance, in a building already erected, this cable can be fished between the floors and in the partition walls, where it would be impossible to install either rigid conduit or flexible steel conduit without disturbing the floors or walls to an extent that would be objectionable.

Armored cable is less expensive than the rigid conduit or the flexible

steel conduit, but more expensive than cleat wiring or knob and tube wiring, and is strongly recommended in preference to the latter.

Where the cable is subject to moisture, as on the outside of a building or underground, *lead covered armored cable* must be used.

The difference between the latter and the ordinary armored cable is that a continuous lead sheath is placed over the wires and the whole is then covered with the flexible steel.



FIGS. 5,382 and 5,383.—Right and wrong way to cut armored cable.

Cutting Armored Cable.—In order to properly remove the metal casing or armor, a fine toothed hack saw should be used, (24 teeth to the inch) or a special tool, such as shown in 5,393.

The armor is cut diagonally across. The cut should not entirely cut through the sheath, but should be deep enough so that it will break if given a slight inward bend. Do not cut too deep as this may sever the wires or puncture the insulation.

Figs. 5,382 and 5,383 show right and wrong methods.

After armor sheath has been removed, the outer protecting braid must be removed from the duplex conductors. This is best done by making a

slit one inch below the sheath about one inch long, and then by pulling the outer braid it will readily come off without much effort.

Before the cable is installed it should be examined at each end to see whether any part of the sheath punctures the insulation.

This is very important as grounds and short circuits are often thus accidentally made.

In order to protect the insulation on the conductor from being cut by the sharp edge of armor a bushing is inserted.

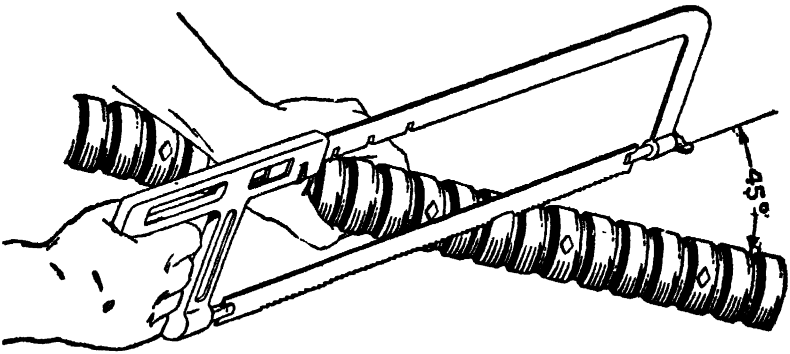


FIG. 5,384.—*Preparing National cable end for installation 1. Cut armor.* Quickest method of cutting armor is as shown, holding hacksaw at 45° angle to cable. The cut should be made several inches from the end to allow for making joint in outlet box.

The method of cutting, stripping and inserting the bushing is shown in figs. 5,384 to 5,391. The importance of bushing the end of a cable is shown in fig. 5,392.

Installation of Armored Cable.—In the work of installing the cable, the outlet boxes should be located and installed first. The boxes can thus be used as guides for boring the holes. It is advisable to bore all the holes before installing the cable.

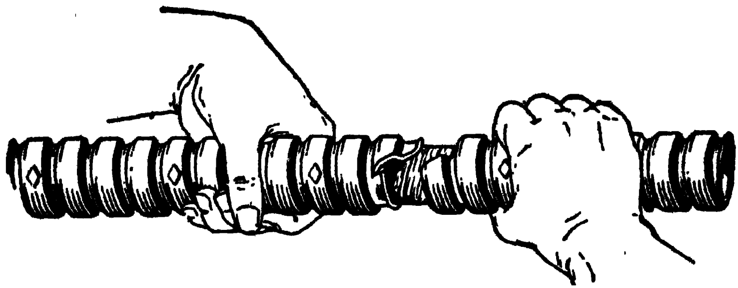


FIG. 5,385.—*Preparing National cable end for installation 2. Twist off armor.* It will easily twist off over conductors, after convolution has been sawed through

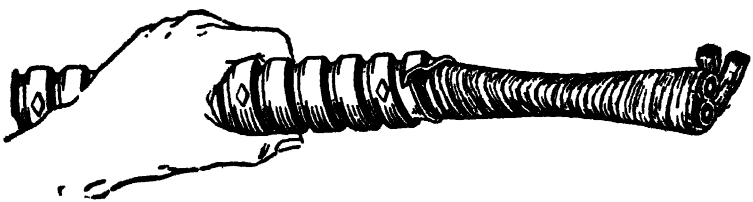


FIG. 5,386.—*Preparing National cable end for installation 3. Remove armor.* Underneath the armor is the *Kraft armor*, or protective covering wrapped over the insulated conductors.

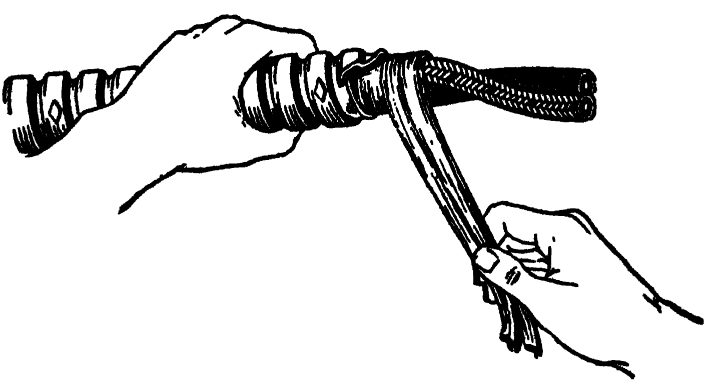


FIG. 5,387.—*Preparing National cable end for installation 4. Unwind protective covering.* This is easily done as shown.

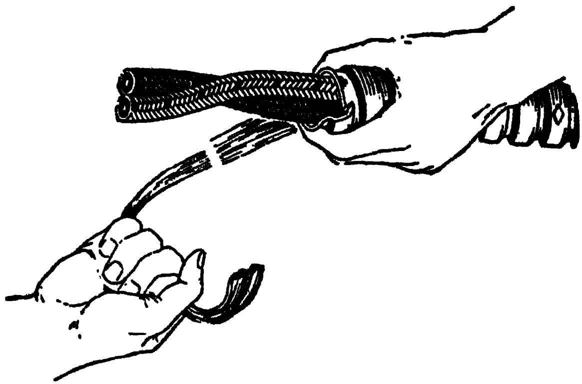
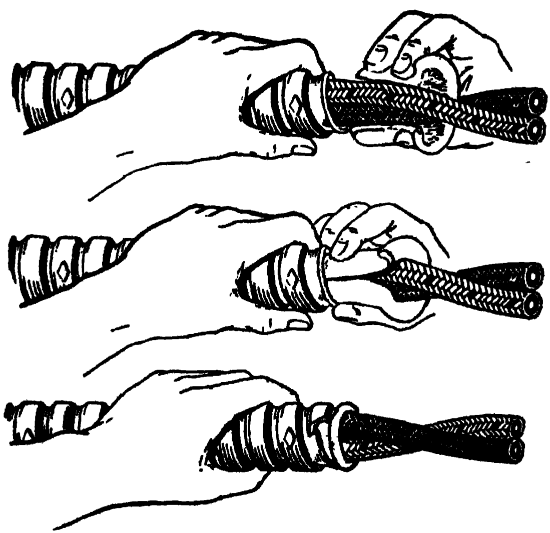


FIG. 5,388.—*Preparing National cable end for installation 5. Break off protective covering.* This will easily snap off by hand.



FIGS. 5,389 to 5,391.—*Preparing National cable for installation 6. Insert bushing.* This bushing protects the insulation from being cut by the edge of the armor. It is placed around the conductors as shown in figs. 5,389 and 5,390 and is pushed inside the armor as in fig. 5,391

Holes should be bored through floor beams at right angles instead of inclined as it makes it easier to pull through the cable.

In order to avoid undue fatigue in boring, the holes may be bored between two outlets and then insert cable, rather than bore all the holes before inserting cable.

To insert cable, take the roll of cable and after preparing the end as explained in the preceding section, thread the cable

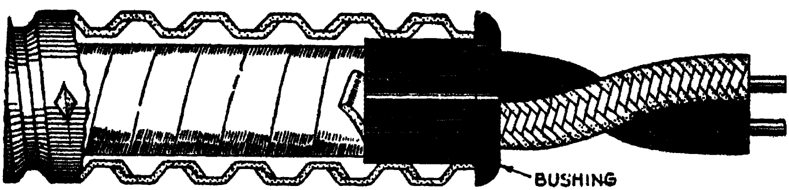


FIG. 5,392.—Detail of National armored cable with end cut and bushed, showing how the bushing protects the conductor insulation from the ragged edge of the cut armor.

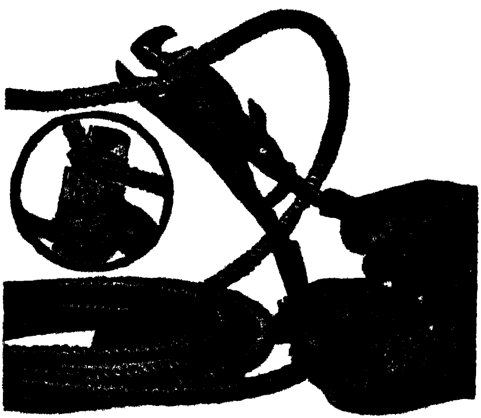


FIG. 5,393.—Austin armored cable tool. Strips the armor from any single strip armored cable in sizes 14-2, 14-3, or 12-2, without any possibility of injuring the insulation of the wire. Cuts cable, wire or non-metallic flexible conduit up to ½ in. outside diameter. Has auxiliary pliers with extra leverage. In using the cutter, slip the tool on the cable, open the handles as far as they will go, then close the handles. The armor is not severed cleanly, the cable slips out of the tool Do not attempt to sharpen the blades; use new ones.

through the holes up to the outlet box and fasten it with a clamp or connector to the outlet box.

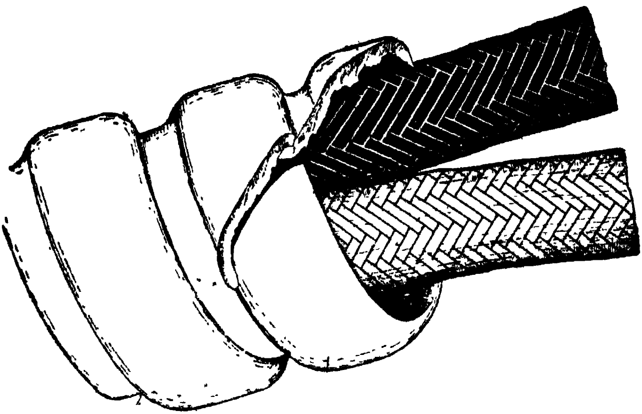


FIG. 5,394.—Armor as cut, showing the ragged edge along the cut. Unless a bushing be inserted to protect the conductor insulation from the ragged sharp edge of the armor, the insulation may be pierced, resulting in a short circuit

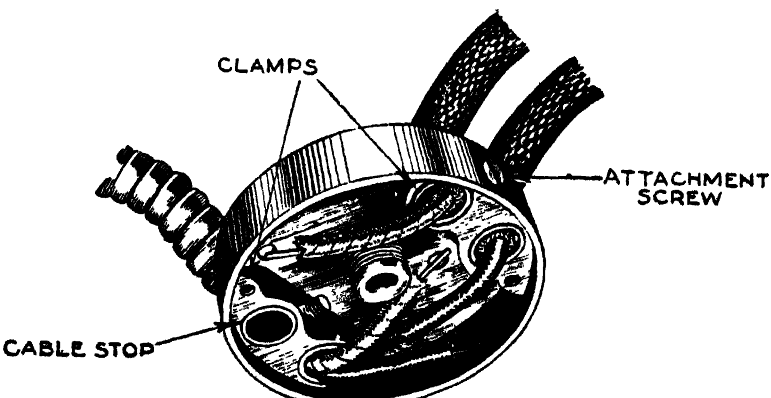
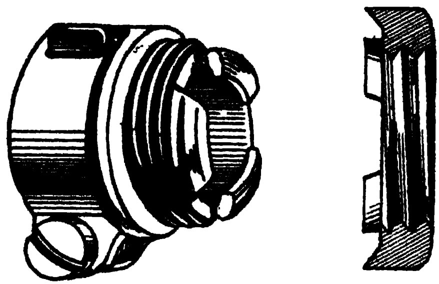


FIG. 5,395.—National clamp type box for armored cable. A few turns of a screw driver securely fastens the cable in place. This box will also take loom or both loom and armored cable in the same box.

Fig. 5,395 shows a box arranged for clamping. One form of connector is shown in figs. 5,396 and 5,397 and the method of connecting it to the cable and box in figs. 5,398 to 5,404. Another view of the box and completed connector is shown in fig. 5,404.

After fastening the cable to the outlet box, it is pulled fairly taut and cut off at the proper point to connect up with the other box.



FIGS. 5,396 and 5,397.—National connector and lock nut showing detector or lugs which engage with the end of bushing.

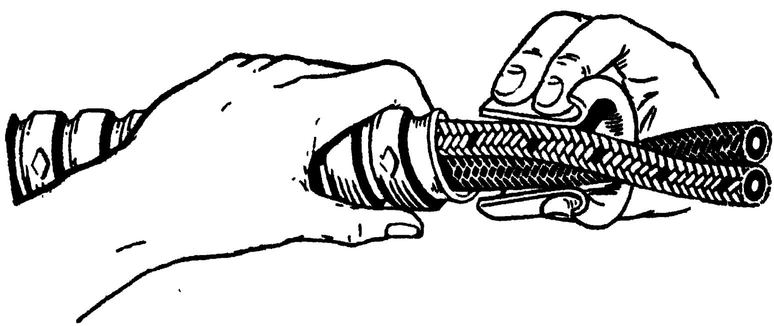


FIG 5,398.—*Connecting cable with box 1.* Place bushing around conductors.

In cutting off the cable be careful to cut it off at the right length so that it will project into the box six inches, or far enough to properly make a joint.

If the cable be cut off too short it will be necessary to remove it and put in another cable of the right length as *joints are not allowed between boxes*, hence the importance of being careful to cut off the right length of cable.

When the cable runs parallel with joists or studs, it is fastened to them with pipe clamps.

In wiring an old house, the procedure is similar to that in a concealed knob and tube installation. The cable must be fished from outlet to outlet and then must be fastened into the outlet boxes.

Being metallically sheathed, the wires need no additional protection.

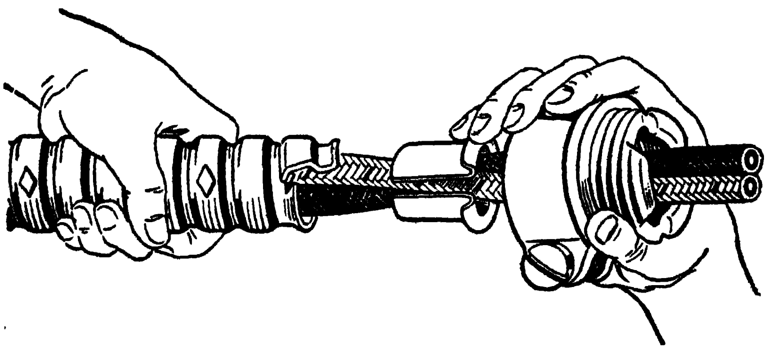
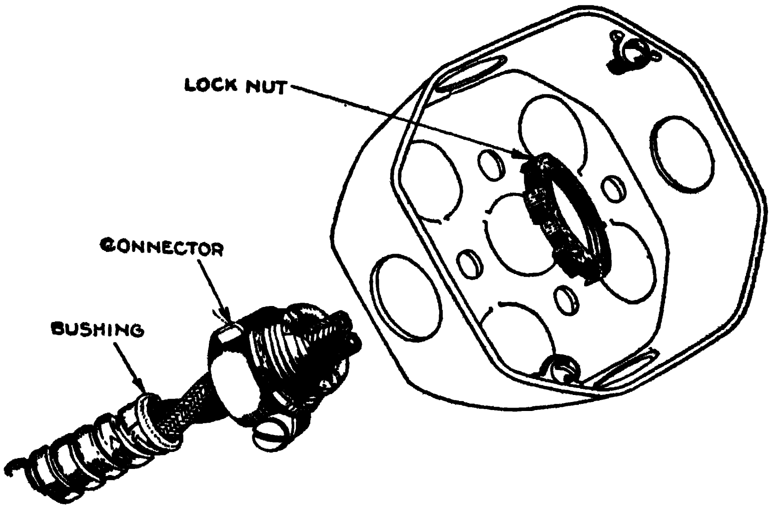


FIG. 5,399.—*Connecting cable with box 2.* Thread conductors through connector. The latter slides down on cable so that end holds the bushing in protective position inside of cable and the cutaways or open spaces between the lugs permit wireman or inspector to see that the bushing is in place.

FIG. 5,400.—*Connecting cable with box 3.* Secure connector to cable by tightening screws.



FIGS. 5,401 to 5,403.—*Connecting cable with box 4.* Thread conductors and end of connector through knockout of box and put on nut.

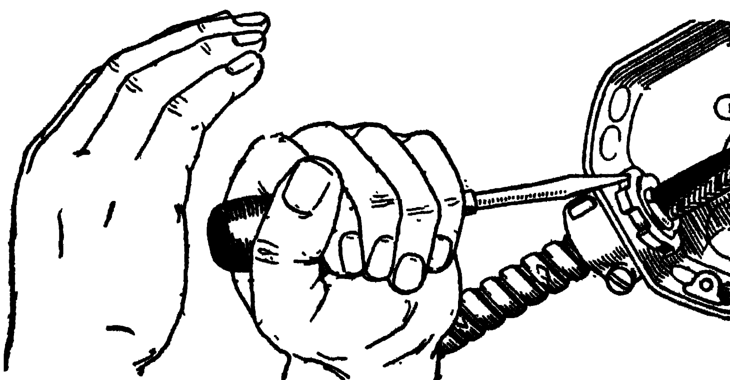


FIG. 5,404.—*Connecting cable with box 5.* Tighten lock nut. This finishes the operation. It will be noticed that the type nut shown can be tightened with a screw driver, which may be an easier method than using a wrench in cramped positions.

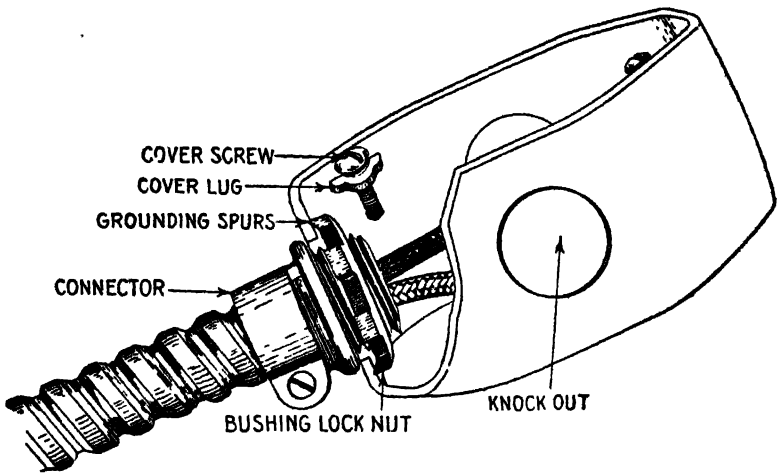


FIG. 5,405.—National connector connected to outlet box showing bushing.

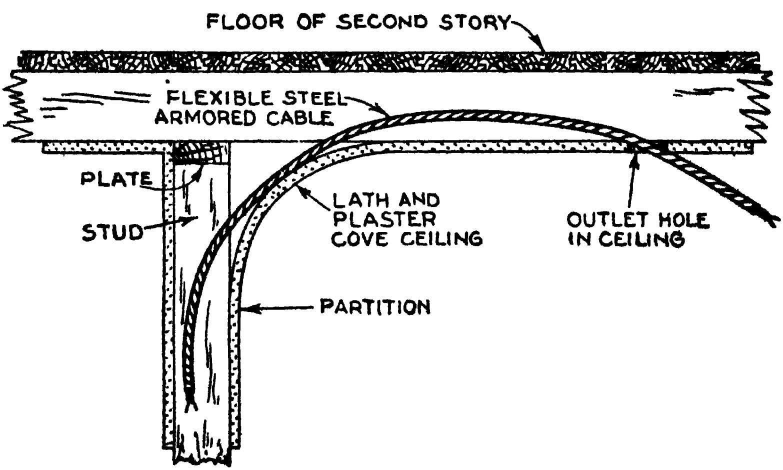


FIG. 5,406.—Method of passing armored cable through walls, ceilings, partitions, etc.

It is advisable to fasten the armored cable to timbers by means of pipe straps, wherever access permits this to be done.

Fig. 5,406 shows method of forcing armored cable around a cove ceiling.

Make all bends as gradual as possible to avoid opening the armor, as would occur at sharp bends. Secure the armored conductor at all exposed bends, and especially when it is used around machinery. Figs. 5,407 and 5,408 show right and wrong way to make a bend.

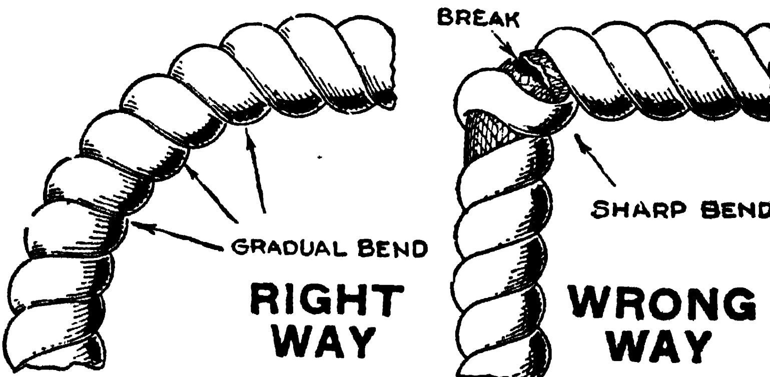


FIG. 5,407 and 5,408.—Right and wrong way to bend armored cable.

FIG. 5 408-1.—Illustrating typical armored cable as packed for shipment.

Installations of armored cable shall comply with the requirements of the National Electrical Code.

Armored cable (Type AC or ACT) may be used for both exposed and concealed work in dry locations, for underplaster extensions as provided by the N.E.C.; and imbedded in plaster finish on brick and other masonry, except in damp or wet locations. Armored cable (Type ACV) in sizes No. 4 and larger, may be used for exposed work in dry locations in buildings occupied for industrial purposes.

Armored cable shall contain lead-covered conductors (Type ACL) if used where exposed to the weather or to continuous moisture, for underground runs and embedded in masonry, concrete or fill in buildings in course of construction, or where exposed to oil, gasoline or other conditions having a deteriorating effect on the insulation.

Armored cable may be run or fished in the air voids of concrete masonry block or tile walls where such walls are not exposed or subject to excessive moisture or dampness.

Armored cable shall not be used (1) in theaters, except as provided in the N.E.C.; (2) in moving picture studios; (3) in hazardous locations; (4) where exposed to corrosive fumes or vapors; (5) in storage battery rooms; (6) on cranes and hoists, nor (7) in hoistways or on elevators, except as provided in the *National Electrical Code.*

Armored cable shall be secured by approved staples, straps or similar fittings, so designed and installed as not to injure the cable. Cable shall be secured at intervals not exceeding 4½ feet and within 12 inches from every outlet box or fitting, except where cable is fished and except lengths of not over 24 inches at terminals where flexibility is necessary.

Exposed runs of cable shall closely follow the surface of the building finish or of running board except:

1. Lengths of not more than 24 inches at terminals where flexibility is necessary.

2. In accessible attics and roof spaces.

3. On the underside of floor joists in basements where supported at each joist; and so located as not to be subject to mechanical injury.

All bends shall be so made that the armor of the cable will not be injured and the radius of the curve of the inner edge of any bend shall be not less than 5 times the diameter of the cable.

TEST QUESTIONS

1. *Describe the construction of an armored cable.*
2. *Name two kinds of armored cable.*
3. *What are the advantages and disadvantages of armored cable?*
4. *Is armored cable as expensive as rigid or flexible conduit?*
5. *What kind of cable should be used in damp places?*
6. *Describe the proper method of cutting armored cable.*
7. *What should be done before installing cable?*
8. *How is the conductor insulation protected from the sharp edge at the end of the cable?*
9. *Describe the method of cutting, stripping and inserting the bushing.*
10. *Explain in detail the method of installing armored cable.*
11. *Explain how the cable is attached to an outlet box.*
12. *What precaution should be taken in cutting the cable?*
13. *If the cable be cut too short, what must be done?*
14. *How is the cable secured when it runs parallel with joists or studs?*
15. *What method is followed in wiring an old house?*
16. *How is a snake used in passing the cable through walls?*
17. *How should bends be made?*
18. *What happens to the cable if the bend be too short?*

19. *What should be done with exposed bends?*
20. *What should be done in order to avoid undue fatigue in boring holes?*
21. *Describe the method of inserting cable.*
22. *What tool is used in cutting a cable other than a hacksaw?*
23. *How is a connector secured to a cable?*

CHAPTER 108

Wiring in Flexible Conduit

A flexible conduit consists of a continuous flexible steel tube composed of convex and concave metal strips, wound spirally upon each other in such a way as to interlock their concave surfaces.

It possesses considerable strength and can be obtained in long lengths (50 to 200 feet); elbow fittings are not required as the conduit may be bent to almost any radius. The fissures of the conduit provide some ventilation; this is an advantage in some places and a disadvantage in others.

Flexible conduit should not be used in damp places because of the fissures through which moisture may enter.

Although flexible conduit is easy to handle, because it is flexible, it is not desirable to install an entire wiring job with this kind of conduit. It is better combined with rigid conduit for extensions having short and irregular runs, thus avoiding extra and difficult pipe fitting.

Flexible conduit provides a method of passing through joists and studs, avoiding notching. Flexible conduit is made in two types.

1. Single strip;
2. Double strip.

The single strip flexible conduit is made of *one* continuous length of electro-galvanized steel strip, with the edges turned to interlock, as shown in fig. 5,409.

This construction is approved for service under the most rigorous conditions—severe bending or pulling will not separate the joints. The uniform convolutions in single strip conduit have a flattened outside surface which makes the conduit easy to pull through holes and the smooth even inside surface allows wires to slide easily in fishing.

FIG. 5,409.—National single strip flexible conduit. Put up in 250 ft. lengths and where under 250 ft., in lengths that work out in multiples of 5 ft. from 100 to 250 ft.

Double strip flexible conduit is made of *two* electro-galvanized steel strips, turned at the edges, and wound so that the strips of the outside armor *key* into the edges of the inside strips, as shown in fig. 5,410.

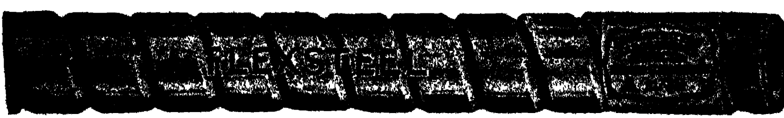


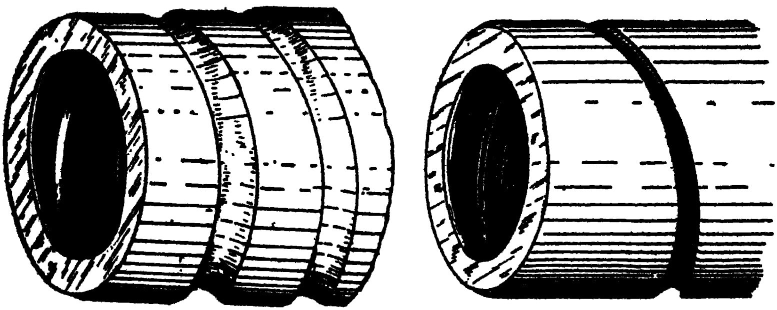
FIG. 5,410.—National double strip flexible conduit. Can be had in the same lengths as the single strip cable.

This gives a double armor for protection of conductors, having greater flexibility, and greater resistance to injury and strain. The long convolutions, flat inside and outside, permit the conduit to pull through holes easily, and provide a smooth wire channel through which to fish wires.

Flexible conduit is used to advantage in many cases where rigid conduits would not be desirable. It is especially adapted to completed buildings where it is desired to install the wiring by "fishing" without greatly disturbing the walls, floors or ceilings.

In installing flexible conduit, it is "fished" under floors, in partitions between the floor and ceiling, by making pockets in the floors, walls or ceilings, say every 15 or 20 feet, and fishing through first a stiff metal wire called a "snake," and then attaching the conduit to same and pulling the conduit in place from pocket to pocket.

On vertical runs, a chain or weighted string is used which is dropped from the outlet to the floor and its lower end located by sound of the chain end or weight striking the floor.



FIGS. 5,411 and 5,412.—Brass terminal bushings or ferrules. Fig. 5,411, single strip bushing; fig. 5,412, double strip bushing.

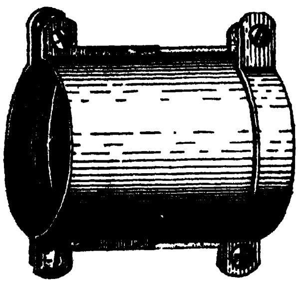
For quick and easy installation in making necessary connections various *fittings* are used with flexible conduit as with other systems. These fittings are suitable for armored cable as well as flexible conduit. They may be broadly classed as:

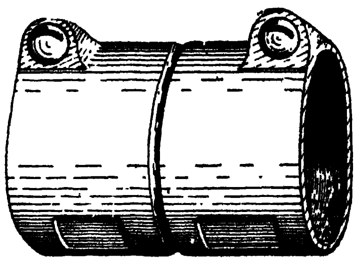
1. Terminal bushings;
2. Couplings;
3. Connectors;
4. Adapters.

Terminal Bushings or Ferrules.—These bushings are used to protect the conductors against abrasion from the raw edge of

the cut armor. Two types of bushing are shown in figs. 5,411 and 5,412.

Couplings.—The object of a coupling is to connect two lengths of conduit. There are several types of coupling and they may be classified:





FIGS. 5,413 and 5,414.—National couplings for connecting flexible conduit to flexible conduit. Fig. 5,413, squeeze type; fig. 5,414, tangent screw type.

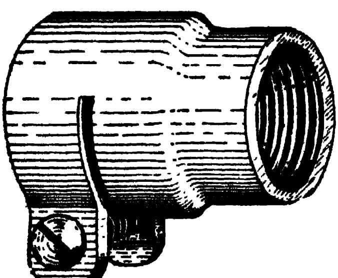


FIG. 5,415.—National squeeze type coupling for connecting flexible to rigid conduit.

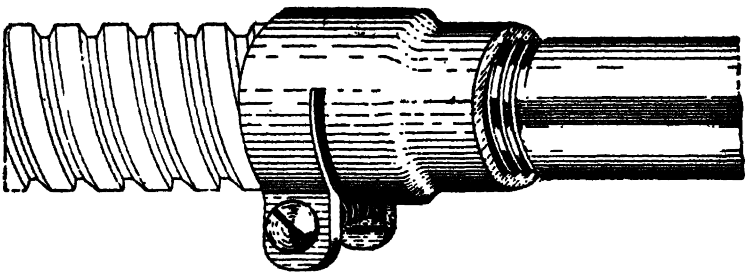
1. With respect to the conduit, as

a. Single strip flexible to single strip flexible conduit
b. Double " " " double " " "
c. Single " " " rigid conduit
d. Double " " " " "

These various types of couplings are shown in figs. 5,413 to 5.415 and connections in figs. 5,418 and 5,419.

These couplings are an essential part of the economical installation of flexible conduit, as they make possible the use of short ends. At least one coupling should be ordered with every coil conduit.

Connectors.—These fittings are used for connecting the conduit to devices such as outlet boxes. There are several types adapted to the different requirements, and they may be classified as



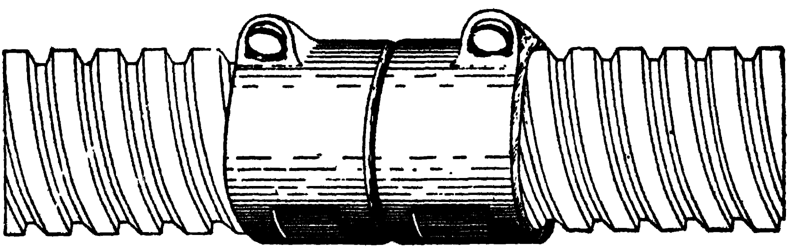


Fig. 5,416.—Flexible to flexible conduit connected by coupling.

Fig. 5,417.—Flexible to rigid conduit connected by coupling.

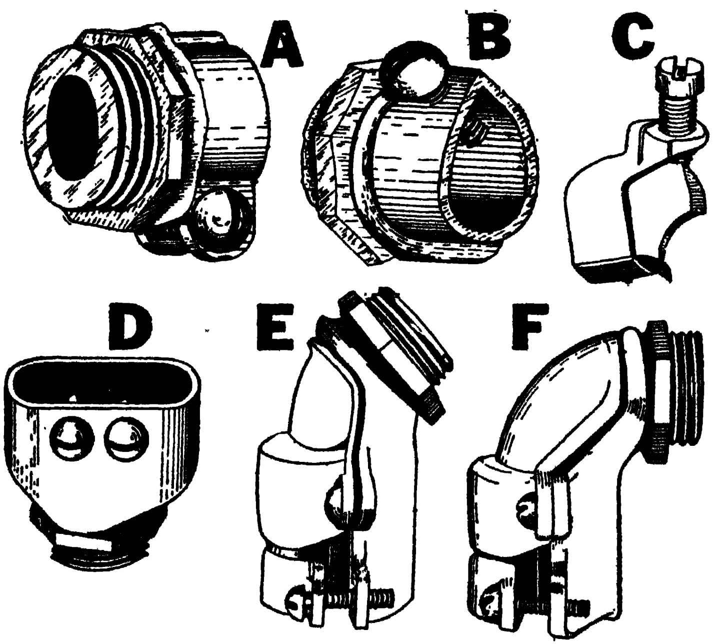
1. Squeeze;
2. Set screw;
3. Slip in;
4. Duplex;
5. Angle.

These various classes of connector are shown in figs. 5,418 to 5,423.

Squeeze connectors are designed to give a firm grip entirely around the armor. They are made of malleable iron, galvanized, and are supplied with lock nuts.

Set screw connectors are provided with a strong tangential screw which is forced between the armor and the side of the connector. As the screw normally follows the groove of the armor, it is virtually impossible for the armor to work loose.

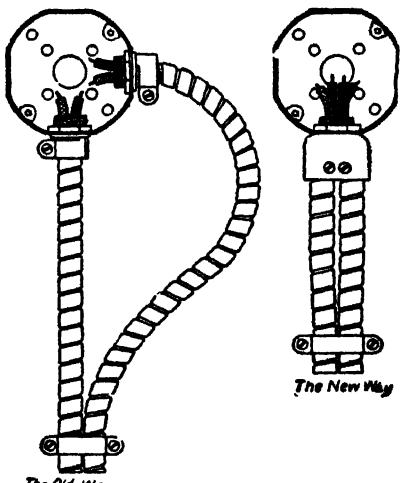
Slip in connectors are designed for quick work. This type connector



FIGS. 5,418 to 5,423.—Various General Electric connectors. A, squeeze; B, set screw; C slip in; D, duplex; E, 45° angle; F, 90° angle.

needs no lock nut, and is so easy to install that it is a valuable time saver. Just run the end of the conductor through the connector, slip the connector into the knock out and tighten the set screw. It is made of malleable iron, galvanized.

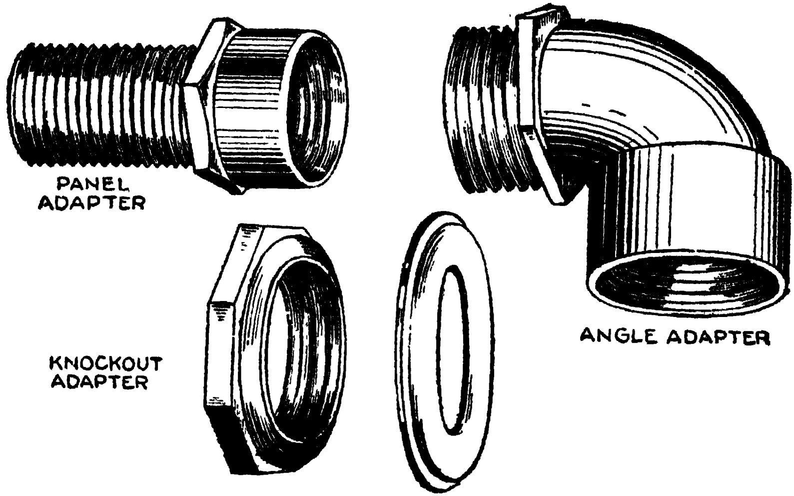
Duplex connectors are used in installations where it is desired to run two conductors into one knock out. One duplex in place of two separate connectors in two different knock outs, saves time in installing, makes a much neater job, saves cable, and doubles the effective number of outlets. This latter feature is quite important when one or two of the knock outs are inaccessible. The duplex is made of malleable iron, galvanized, and



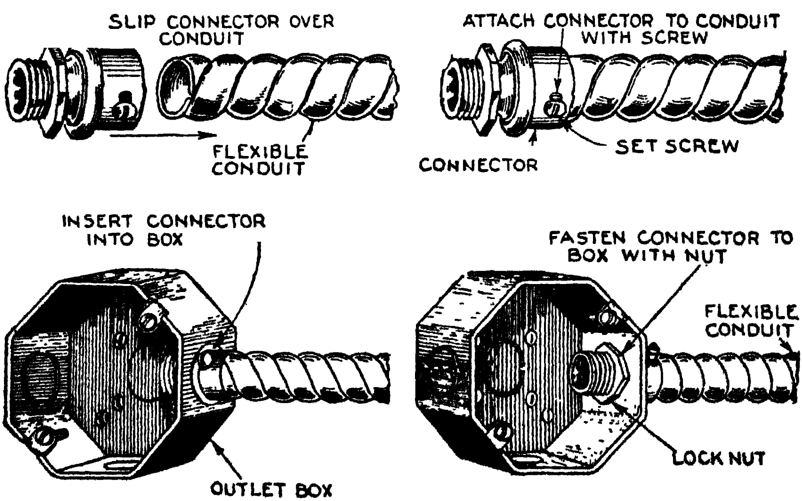
FIGS. 5,424 and 5,425.—Comparison of separate and duplex connectors. The duplex connector takes less time to install than two single connectors, and insures a neater job. A saving of 6 ins. of cable is effected also, at every outlet of the kind indicated.

is of the tangential set screw type. The advantage of using a duplex instead of two connectors is shown in figs. 5,424 and 5,425.

Angle connectors are for the purpose of connecting the conduit at an angle to devices such as outlet boxes. They are designed to connect at angles of 45° and 90° as shown in figs. 5,422 and 5,423. In practically every flexible installation, a few of these convenient connectors will save time and make a better job, as they make possible close fitting work in cramped locations.



FIGS. 5,426 to 5,429 —Various General Electric adapters.



FIGS. 5,430 to 5,434.—Connecting flexible conduit to outlet box, showing the various operations.

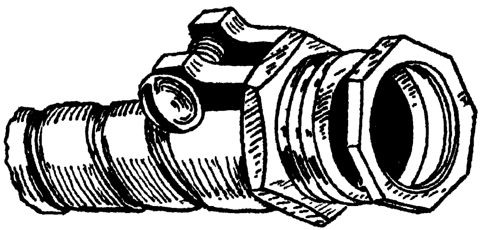
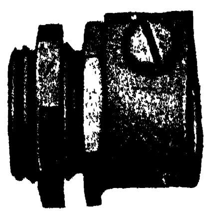
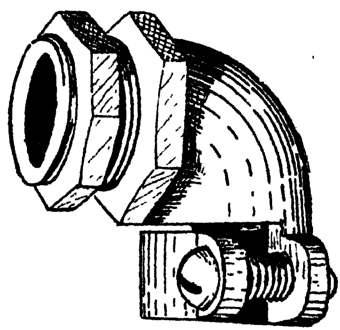
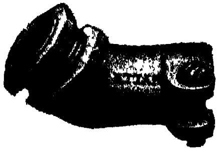


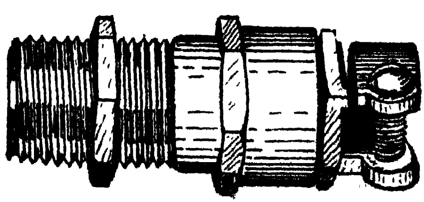
FIG. 5,435.—Rattan straight squeeze connector.





FIGS. 5,436 and 5,437.—Rattan connectors. Fig. 5,436 straight set screw connector; fig. 5,437, 90° angle squeeze connector.





FIGS. 5,438 and 5,439.—Rattan connectors. Fig. 5,438, 45° angle squeeze connector; fig. 5,439, straight panel box squeeze connector.

Adapters.—All threaded connectors for the prevailing sizes of armored conductors and flexible conduit are designed for ½ inch knockouts, but by the use of an adapter, it is possible to use them equally as well with ¾ inch knock outs.

It is an invaluable device for connecting armored conductors or flexible conduit to condulets which have only the ¾ inch knock out. Any threaded connector may be used as a *panel* connector by connecting with this adapter. This fitting converts any straight, threaded connector into a 90° angle connector. Figs. 5,426 to 5,429 show various types of adapters.

How to Connect Conduit to Outlet Box.—After cutting the conduit to proper length and reaming the end, the connector is slipped over the end of the conduit as in fig. 5,430, and fastened to the conduit as in fig. 5,431.

Insert the connector through the knock out in box and put on lock nut as in fig. 5,432. A bushing is next screwed on as in fig. 5,433. When a bushing is used, the lock nut may be placed either inside the box or on the outside.

TEST QUESTIONS

1. *What is a flexible conduit?*
2. *In what lengths is it manufactured?*
3. *Where should flexible conduit not be used?*
4. *Is it desirable to install an entire wiring job with flexible conduit?*
5. *Name two types of flexible conduit.*
6. *Where is flexible conduit used to advaniage?*
7. *How is flexible conduit installed under floors, between partitions or between walls?*
8. *What is provided for quick and easy installation?*
9. *Classify the various fittings used.*
10. *What are terminal bushings or ferrules used for?*
11. *Name several types of couplings.*
12. *What is a connector, and what are the various types*
13. *What are squeeze connectors used for?*
14. *What is the advantage of a slip in connector?*
15. *Explain the use of a duplex connector.*
16. *What is an adapter?*
17. *How is flexible conduit connected to an outlet box?*
18. *What should be removed from the box in order to connect a conduit?*
19. *Can a threaded connector be used as a panel connector?*
20. *Draw a sketch showing difference between separate and duplex connector.*

21. *What angles are angle connectors designed for?*
22. *What is the advantage of angle connectors?*
23. *Are the fissures in the conduit an advantage or a disadvantage?*

CHAPTER 109

Wiring with Non-Metallic Sheathed Cable

This type of cable is designed for the wiring of residences and similar buildings of frame or semi-frame construction

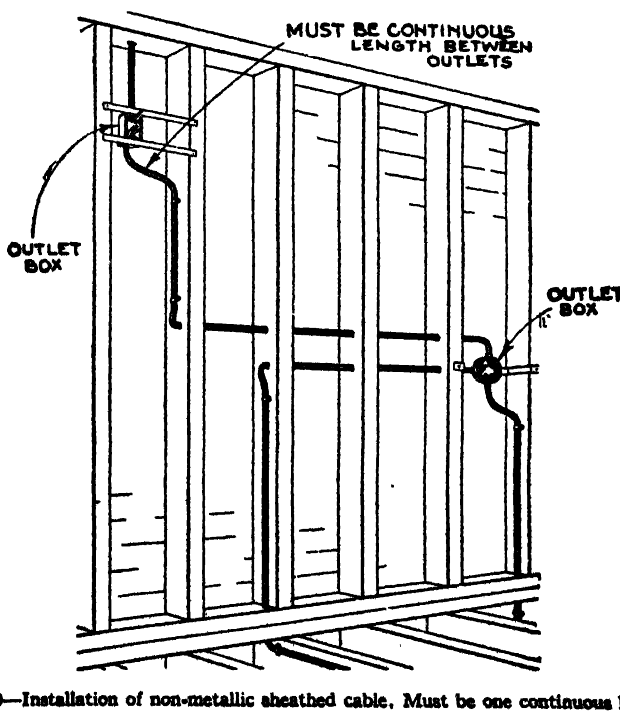
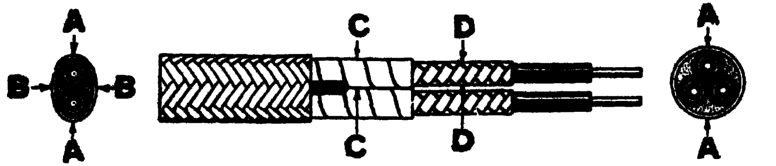


FIG. 5,440—Installation of non-metallic sheathed cable. Must be one continuous length be tween boxes.

which are generally classified as *dry locations*, and in which the difference in pressure between two conductors does not exceed 300 volts.



FIGS. 5,441 to 5,443.—Rome non-metallic sheathed cable. The cable is built up by first sheathing a rubber covered Code wire, in a tough, closely laid jacket of laminated kraft tape, which is permanently held in place by a cotton braid. After saturation with special compounds this semi-finished conductor is armored with a second jacket of long fibre kraft tape, and a fire and moisture resistant compound applied. Two or more of these heavily armored conductors are then gathered, with their reinforcing filler cords, under an extra heavy fabric braid, and the cable given two final impregnations of fire and moisture resistant compounds. Made with conductors ranging in size from No. 14 to No. 8. Reference letters indicate principal dimensions.

FIG. 5,444.—Passing non-metallic sheathed cable through holes bored in beams.

In addition to the usual secondary feeder and circuit wiring of residences and similar properties non-metallic sheathed cable is being widely used for installation of circuits for electric ranges and various other heavy duty domestic appliances.

Most inspection departments permit non-metallic sheathed cable to be installed in cellars, in accessible unfinished attics or roof spaces and in private garages of not more than two car capacity.

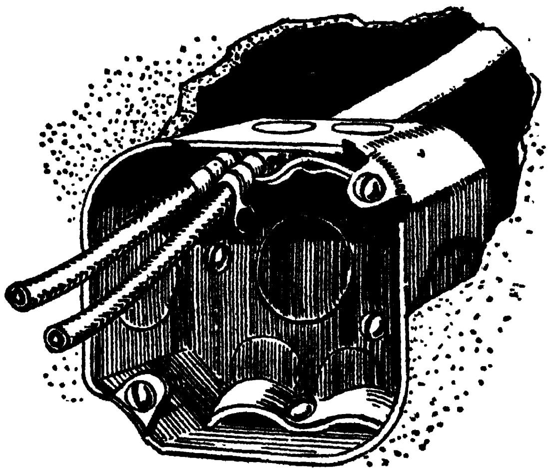


FIG. 5,445.—Romex outlet box for non-metallic sheathed cable.

FIG. 5,446.—Method of removing sheath from ripper corded type of non-metallic sheathed cable by pulling the ripper cord.

The construction of a typical cable, as made by the Rome Wire Co., is shown in figs. 5,441 to 5,443.

Installation of Non-Metallic Sheathed Cable.—This type

FIG. 5,447.—Method of removing undersheath of non-metallic sheathed cable.

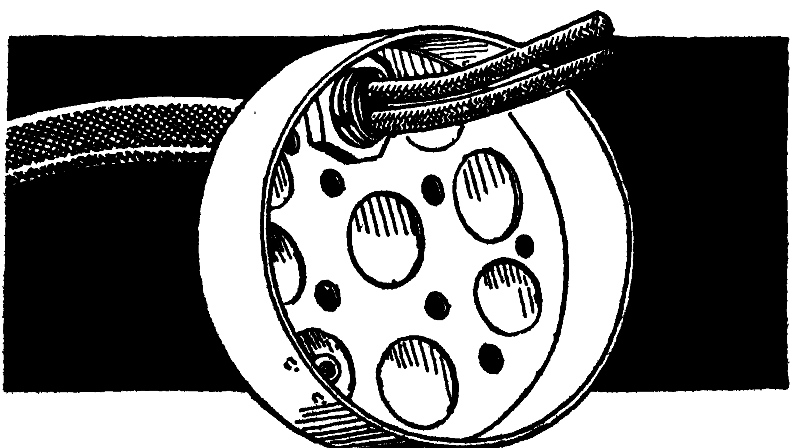


FIG. 5,448.—Non-metallic sheathed cable attached to box with a connector.

cable should be installed on the *loop system* only, that is, in continuous, unbroken runs from outlet to outlet and without joints or splices of any kind throughout the lengths between outlets, as is indicated in fig. 5,444.

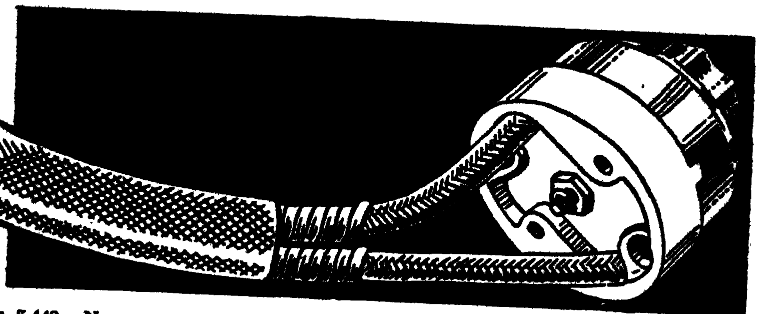


FIG. 5,449.—Non-metallic sheathed cable connected to a snap switch.

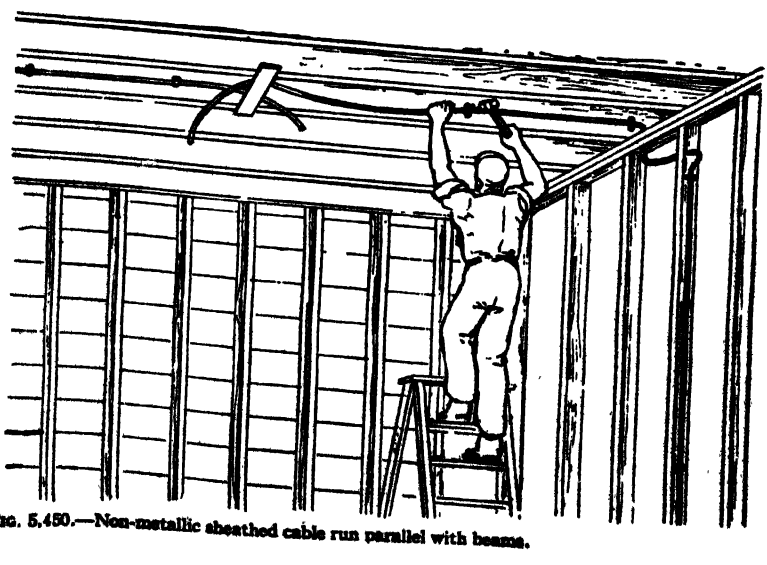


FIG. 5,450.—Non-metallic sheathed cable run parallel with beams.

In fastening the cable, the method shown in fig. 5,451 will suffice where its appearance is not objectionable, but for a neat job, it should be done as in figs. 5,452 and 5,453.

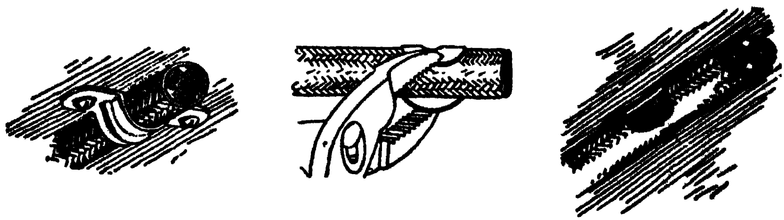
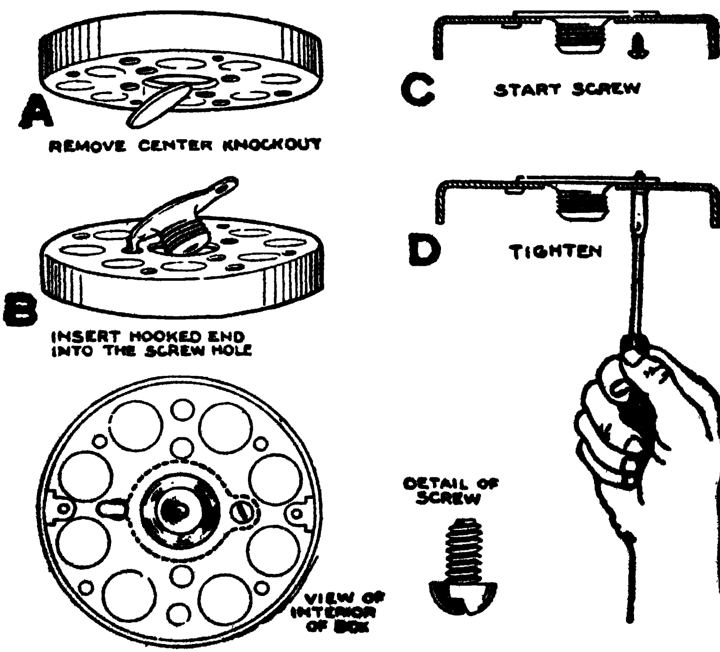
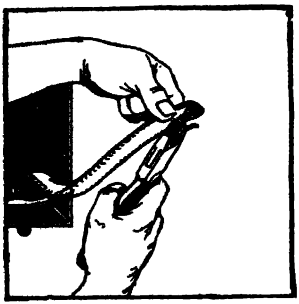


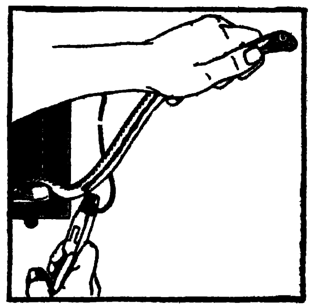
FIG. 5,451.—Method of fastening non-metallic sheathed cable with straps.
FIG. 5,452 and 5,453.—Method of fastening non-metallic sheathed cable with clips.

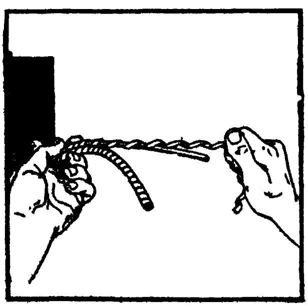


FIGS. 5,454 to 5,459.—Attachment of fixture stud to box.

Non-Metallic Sheathed Cable at Outlets.—Almost any type of outlet plate or box for armored cable may be used with the sheathed cable as the cable enters and is very tightly gripped by most clamping devices.







FIGS. 5,460 to 5,462.—Stripping Rome non-metallic sheathed cable. Nick the end of "Romex" with a knife and grip either one of the ripped parts, as shown in fig. 5,460; rip open the desired length of the outer braid, as in fig. 5,461, and spin off the outer tape as in fig. 5,462. To provide plenty of room for splices and outlet boxes, the outside tape should be trimmed off back to the outer braid.

Fig. 5,463 shows typical outlet plate used at outlets on old jobs. Figs. 5,464 and 5,465 show types of pans or shallow boxes at outlets. When sheathed cable is used with a fitting having threaded hubs for conduit or with a box having knock outs for conduit, squeeze connectors should be used as shown in figs. 5,466 and 5,467.

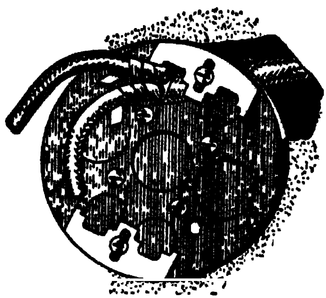
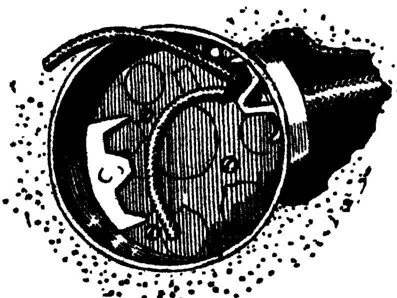


FIG. 5,463.—Typical outlet plate as used for RomeX, and other wire outlets upon old jobs. Romex plates are designed for use at such outlets where conditions do not require the use of an outlet box. Knockouts are provided, each of which will accommodate two non-metallic conduits. The special clamps securely hold the loom against all strains. A centrally located knockout is provided for gas pipe or fixture stud mounted on bar hanger. Clearance holes allow mounting fixture stud on the plate itself.



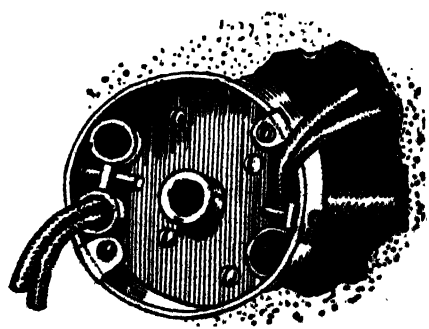


FIG. 5,464 and 5,465.—Shallow outlet boxes for non-metallic sheathed cable wire.

Non-Metallic Sheathed Cable in Cellars.—In many localities the use of rigid conduit in cellars is required, but in districts where such rules do not exist most inspection departments permit the use of non-metallic sheathed cable, providing the cable be tightly strapped to the faces or to the sides of timbers when running with them or is well strapped to running boards or guard strips where carried across timbers, as shown in fig. 5,474.

FIGS. 5,466 and 5,467.—Connectors for two and three wire non-metallic sheathed cable.

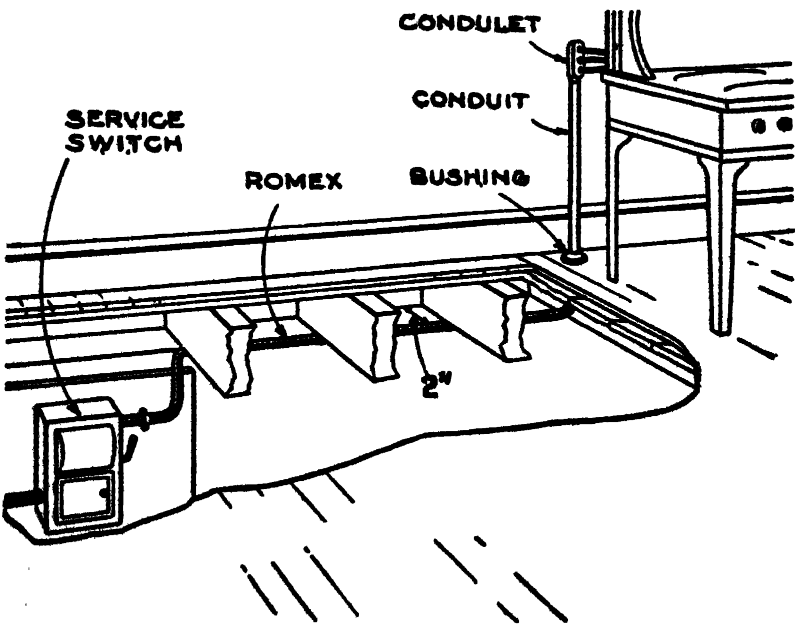
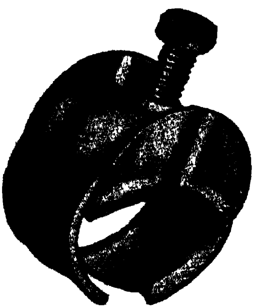


FIG. 5,468.—Wiring with Romex for service switch to electric range showing method of passing through floor, and terminal fitting.

Non-Metallic Sheathed Cable on Side Walls.—When used for open wiring in small private garages, basements, farm houses



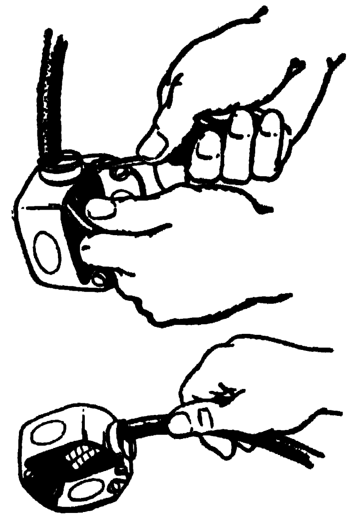
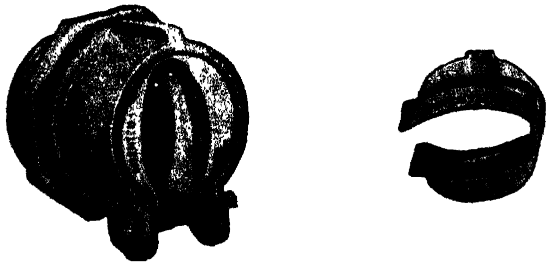


FIG. 5,469.—Steel City connector for non-metallic sheathed cables and flexible tubing. This connector can be installed outside or inside of a box.

FIGS. 5,470 and 5,471.—Method of installing Steel City connector for non-metallic sheathed cable and flexible tubing. *To install*, snap connector into knock out; insert cable or tubing and tighten screw.



FIGS. 5,472 and 5,473.—Steel City connector for non-metallic sheathed cable and flexible tubing. Fig. 5,472, connector assembled; fig. 5,473. The insert is so designed that the non-metallic flexible cable is held in the center of the connector so that when the strap is tightened down no sharp curve or bend is put in the conductor. The insert presents a long bearing surface to the conductor.

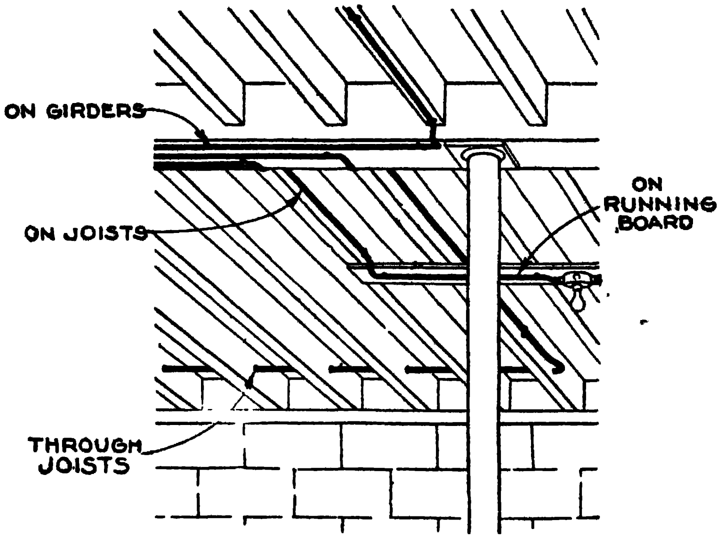


FIG. 5,474.—Method of running non-metallic sheathed cable in cellars.

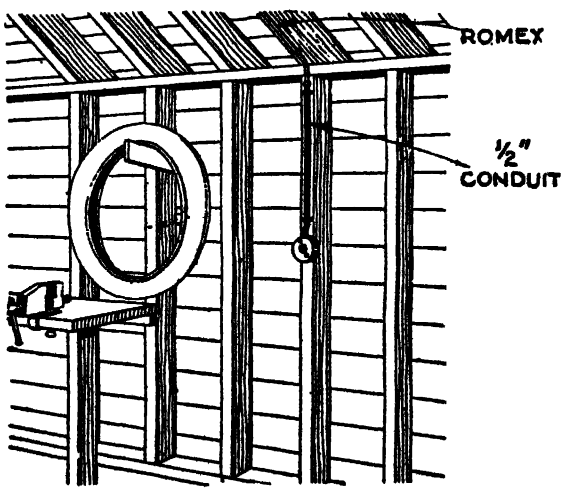


FIG. 5,475.—Method of running non-metallic sheathed cable in side walls.

and similar classes of property, non-metallic sheathed cable should be protected on side walls with either wood boxing, conduit or ordinary pipe extending upward to a point at least seven feet above the floor, similarly as shown on page 3,204.

Non-Metallic Sheathed Cable in Attics.—When run in accessible attics or roof spaces, non-metallic sheathed cable

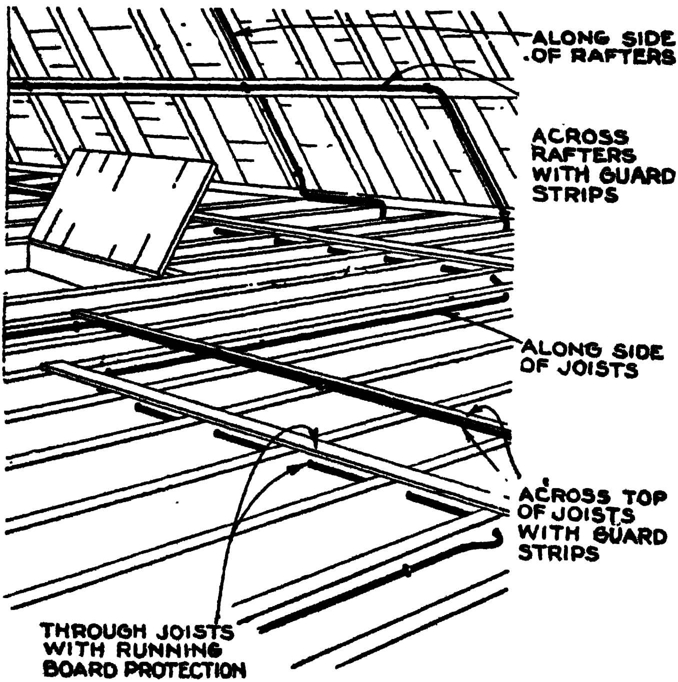


FIG. 5,476.—Method of running non-metallic sheathed cable in attics.

should preferably be either strapped to sides of joists, or if running at angles with the joists should be carried through bored holes and covered with a running board, as shown in

fig. 5,476. Most inspection departments permit non-metallic sheathed cable to be run on top of timbers in attics only when runs are along under side of roof timbers or are well back from scuttle openings.

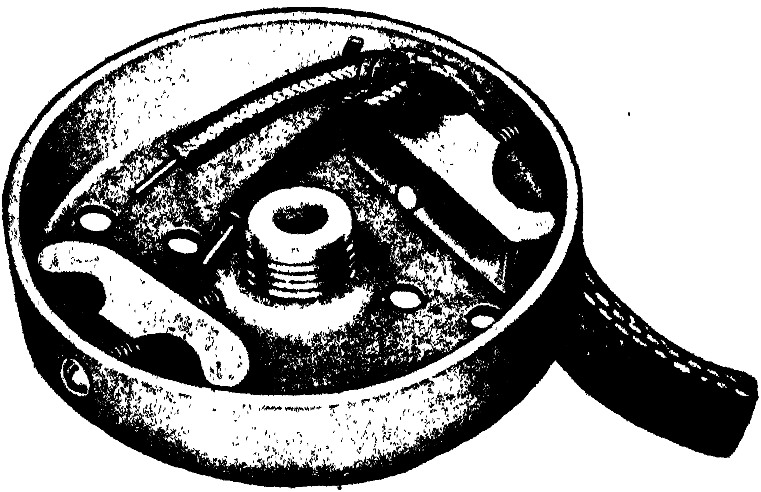
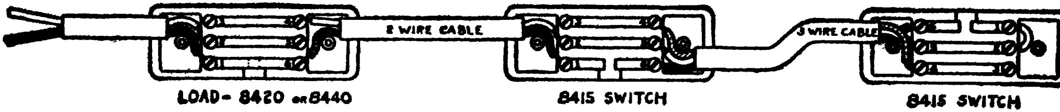


FIG. 5,477.—National outlet box for loom and loom wire. Double grip clamp for loom. Brass ferrule in addition should be used for armored cable. Extra knock outs for cable or loom and screw hole for extra clamp. This box also takes armored cable.

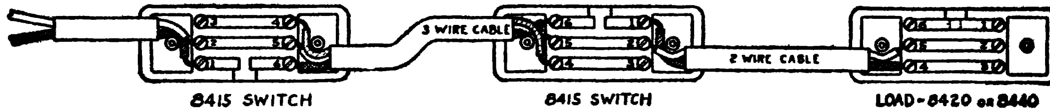
Due to the limited capacity of the conductors non-metallic sheathed cable has few applications for industrial use.

Non-metallic sheathed cable contains two, three or four insulated conductors encased in heavy insulating protective covering, with or without a ground wire. Additional protective covering must, however, be provided when the cable is installed.

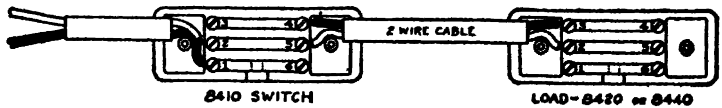
The cable is made in standard sizes from No. 14 to No. 4 A.W.G. and its use is limited to circuits of 600 volts or less. The two-conductor cable is oval shaped, whereas, the three and four conductor cable is round. Conductors are solid in sizes from No. 14 to No. 10 A.W.G. and in sizes from No. 8 to No. 4 A.W.G. they are stranded.



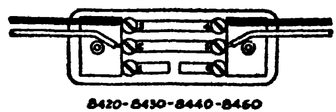
Typical Circuit for two 3-Way Switches with load in line.



Typical Circuit for two 3-Way Switches with load beyond switches.



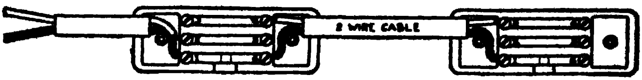
Typical "feed at Switch" Circuit.



Typical connection for load (Convenience Outlet or Lamp Socket) standing across line.

FIGS. 5,477-1 to 5,477-4.—Various fittings used for non-metallic sheathed cable. Switches, outlets and tapping devices of insulating material may be used without boxes in exposed cable wiring, and for concealed work for rewiring in existing buildings where the cable is concealed and fished. Openings in such devices shall form a close fit around the outer covering of the cable and the device shall fully enclose that part of the cable from which any part of the covering has been removed. If connections to conductors are by binding-screw terminals, there shall be available as many screws as conductors, unless cables are clamped within the structure, or unless terminals are approved for the purpose.

Typical "feed-thru" Circuit, with feed at and beyond Switch.



Typical "Dead-End" Switch Circuit

FIG. 5,477-5.—Various wiring devices used for non-metallic sheathed cable.

TEST QUESTIONS

1. *For what service conditions is non-metallic sheathed cable adapted?*
2. *Describe the construction of non-metallic sheathed cable.*
3. *Is non-metallic sheathed cable suitable for heavy duty domestic appliance circuits?*
4. *What is a ripper cord?*
5. *How is the under sheath removed from the conductors?*
6. *Describe in detail the method of connecting the cable to an outlet box.*
7. *What methods are used in fastening the cable?*
8. *Can the cable be used with any type of outlet box?*
9. *When should connectors be used?*
10. *What is an outlet plate?*
11. *Is non-metallic sheathed cable allowed in cellars in all localities?*

12. *Explain two types of connector used.*
13. *What method should be used when cable is run in attics?*
14. *What are the important requirements of inspection departments when non-metallic sheathed cable is run in attics?*

CHAPTER 110

Wiring in Rigid Conduit

By definition, rigid conduit commonly called pipe (but different from ordinary pipe used for other purposes) comes in lengths of 10 ft. or less, and must never be used in sizes smaller than one-half inch pipe or nominal size.

The purpose of electrical conduit is to provide a raceway, either underground or throughout a building for electric wires. The inside surface must be unobstructed, smooth and dry so as to facilitate the pulling in of wire without damage to the insulation and to protect it against deterioration and rot.

Conduit must be ductile. It must be soft enough to thread easily, yet not so soft that the dies will run rather than cut. This is most important in making joints. It is essential that the pipe bend easily without opening welds or flattening at bends.

Galvanized conduit is recommended for use where the conduit is subject to rough usage and where the utmost in rust prevention is desired. It is especially recommended for use in street work, in concrete or masonry construction.

The following table gives the *properties* of rigid conduit and by comparing this table with a table giving the properties of *standard wrought pipe* (see the author's **Engineers and Mechanics Guide**, volume No. 7, Page 2,908) it will be seen that rigid conduit has the same properties as standard wrought pipe (sometimes erroneously called wrought iron pipe).

Properties of Rigid Conduit

Nominal Size	DIAMETERS External	DIAMETERS Internal	Thickness	WEIGHT PER FOOT Plain Ends	WEIGHT PER FOOT Thread and Coupling Min	WEIGHT PER FOOT Thread and Coupling Card	THREADS Threads per Inch	THREADS Length of Thread	COUPLINGS Price Each	COUPLINGS Nominal O D.	COUPLINGS Length	COUPLINGS Weight Pounds	ELBOWS Price Each	ELBOWS Weight per 100 in Pounds	ELBOWS Radius Inches	ELBOWS Offset Inches
¼	.540	.364	.088	.424	.385	.426	18	.57	$0 05	.685	1.000	.043	$0.19	42	4.250	7.500
⅜	.675	.493	.091	.567	.515	.525	18	.57	.06	.875	1.125	.087	.19	53	4.250	7.50C
½	.840	.622	.109	.850	.790	.859	14	.75	07	1.063	1.375	.145	.19	75	4.250	7.375
¾	1.050	.824	.113	1.130	1.050	1.147	14	.76	.10	1.312	1 11/16	.270	.25	120	5.375	8.375
1	1.315	1.049	.133	1.678	1.530	1.701	11½	.94	.13	1.576	1.875	.343	.37	200	5.750	9.500
1¼	1.660	1.380	.140	2.272	2 010	2.307	11½	.97	.17	1.950	2.125	.535	.45	300	7.250	10.875
1½	1.900	1.610	.145	2.717	2.490	2.768	11½	.98	.21	2 250	2.250	.750	.60	427	8.250	12.625
2	2.375	2.067	.154	3.652	3.340	3.770	11½	1 12	.28	2.812	2 625	1.25	1.10	700	9.500	15.250
2½	2.875	2.469	.203	5.793	5 270	5 905	8	1.51	.40	3.276	2 875	1.720	1.80	1300	10.500	17.375
3	3.500	3.068	.216	7.575	6 900	7.741	8	1 57	.60	3.948	3 125	2.500	4.80	1700	13.CC0	19.500
3½	4.000	3.548	.226	9.109	8 310	9.414	8	1.62	.80	4.591	3 625	4 241	10.60	2300	15.000	21.250
4	4.500	4.0.6	.237	10.790	9 820	11.125	8	1.67	1.00	5.091	3 625	4.741	12.25	2700	16 000	22.500
4½	5 000	4.506	247	12.538	11 500	12.900	8	1 72	1.50	5.591	3.625	5.241	18.55	3100	18.000	24.375
5	5.563	5 047	.258	14.617	13 440	15.210	8	1 78	1.65	6.219	4.187	8.000	25.75	5500	24.000	32.000
6	6.625	6.065	.283	18 974	17 700	19 685	8	1 89	2.40	7.358	4.187	10.000	32.00	9000	30 000	39.750

NOTES—All weights and dimensions are nominal.
All weights given in pounds. All dimensions in inches.
The ends of all rigid conduit must be reamed on the inside to remove the burrs.
All rigid conduit ten feet (10') long in finished lengths.
All sizes one and one-half inches (1½") and under are bundled.
Conduit pipe is known and spoken of by its inside diameter.

The electrician who installs rigid conduit should be a good pipe fitter. For this reason, some helpful information on pipe fitting is given in the section following.

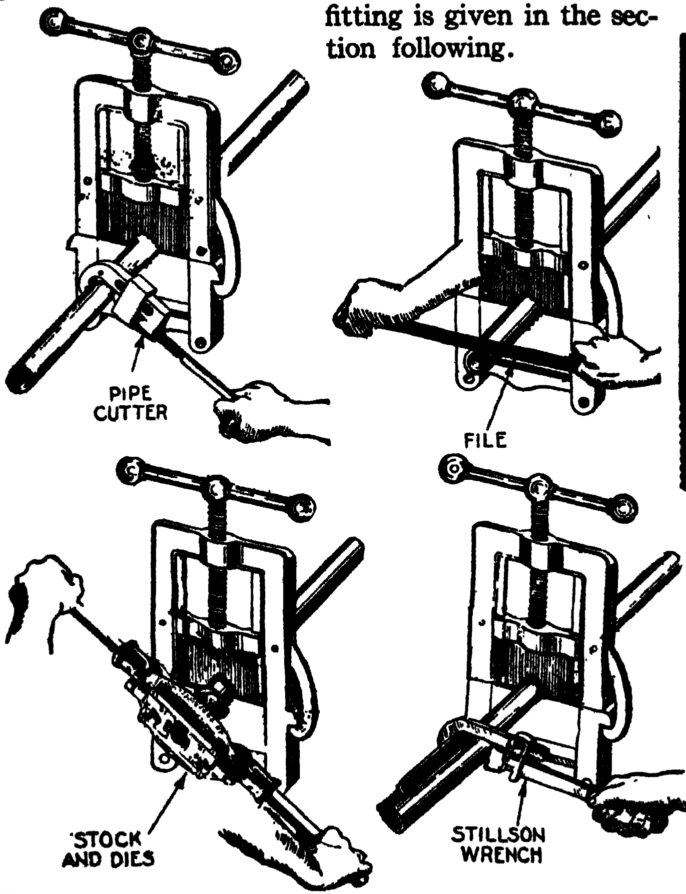


FIG. 5,478.—Rigid conduit. It is manufactured in 10 ft. lengths and comes threaded at both ends with coupling. It has practically the same proportions as standard wrought pipe.

FIGS. 5,479 to 5,482.—Principal operations in pipe fitting. The pipe after being marked to length by nicking with a file is put in a vise and cut with pipe cutter (or hack saw), fig. 5,479; burrs removed with file as in fig. 5,480. Next the thread is cut with stock and dies as in fig. 5,481 and *after carefully cleaning thread with stiff tooth brush*, and applying red lead or pipe cement to the thread just cut, the joint is made up with a Stillson wrench as in fig. 5,482. For interior work, the red lead or pipe cement is omitted, but should be used where conduit runs underground or where exposed to water.

Not all rigid conduit is made of steel, a limited amount being made of aluminum, which has advantages for special conditions.

Aluminum rigid conduit is manufactured in standard wrought pipe and its dimensions are identical with those of steel conduit. It is furnished in ten foot lengths, and is enameled inside to conform with standard practice in manufacturing electrical conduit. It has standard pipe threads, each length being provided with a coupling. Aluminum conduit can be obtained in lengths up to 48 feet. It can be fitted and installed with the same tools and in the same manner as steel conduit.

FIGS. 5,483 and 5,484.—Two types of pipe cutter. Fig. 5,483, Barnes three wheel cutter; fig. 5,484, Saunders wheel and roller cutter.

Pipe Fitting.—The term "pipe fitting" includes the operations which must be performed in installing a pipe system as made up of pipe and fittings. These operations consist of:

1. Pipe cutting;
2. Pipe threading;
3. Pipe tapping;
4. Pipe bending;
5. Assembling.

Cutting.—The conduit should be cut with a hack saw unless the pipes are to be thoroughly reamed afterwards.

In the absence of a hack saw, cutting may be done with a pipe cutter. In either case the conduit is clamped in a pipe vise such as shown in fig. 5,485.

In securing the conduit in the vise, care should be taken (especially when threading) that the jaws hold the pipe sufficiently firmly to prevent slipping, but the clamp screw should not be turned enough to cause the jaw teeth to unduly dig into the pipe.

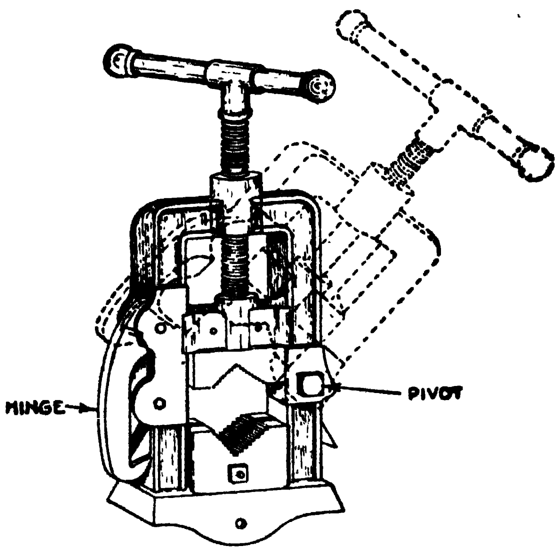


FIG. 5,485.—Ordinary pipe vise. *It consists of* a plain, or hinged (as shown), U-shape piece containing the clamp screw, the sides of which form guides for the upper jaws. The upper and lower jaws are provided with a series of rectangular teeth as shown. When the U piece is closed over the pipe, pin inserted, the teeth of both jaws are brought in firm contact with the pipe by screwing down the upper jaw thus holding the pipe firmly.

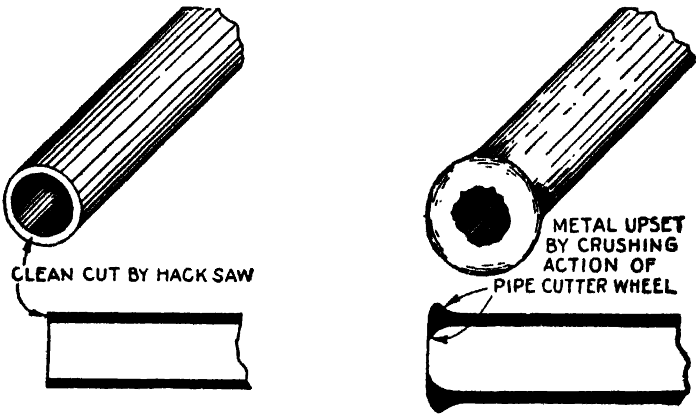
A pipe cutter is a tool which usually consists of a hook shaped frame on whose stem a slide can be moved by a screw. On the slide and frame several cutting discs or "wheels" are mounted and forced into the metal as the whole appliance is rotated about the pipe.

The operation of cutting a pipe can be done quicker with a

pipe cutter than a hack saw, and for this reason the former is more frequently used, although it crushes the metal and leaves a shoulder on the outside and a burr on the inside of the pipe.

This does not apply to the knife type of pipe cutter. The appearance of the cuts made with hack saw and pipe cutter is shown in figs. 5,486 to 5,489.

The external shoulder must be removed to allow the pipe to enter the threading tool so no worry need be given that the



FIGS. 5,486 to 5,489.—Appearance of pipe end when cut by hack saw, and by pipe cutter. When a pipe cutter is used the internal burr must be removed by a burring reamer as in fig. 5,490, and the external burr by a file as in fig. 5,491.

workman will not do this, but *it should be ascertained* **by inspection** *that the internal burr is removed on every cut*, especially on conduit jobs to prevent the possibility of the burr cutting the insulation of the wires which would probably result in a short circuit.

The operation of removing an internal burr by reaming is shown in fig. 5,490.

NOTE.—*With a roller cutter* a cut at right angles to the conduit is always obtained, with a wheel cutter a little care in starting the cut is necessary.

The external burr or shoulder, caused by using a wheel pipe cutter, is removed with a file. Right and wrong methods of filing are shown in figs. 5,491 and 5,492.

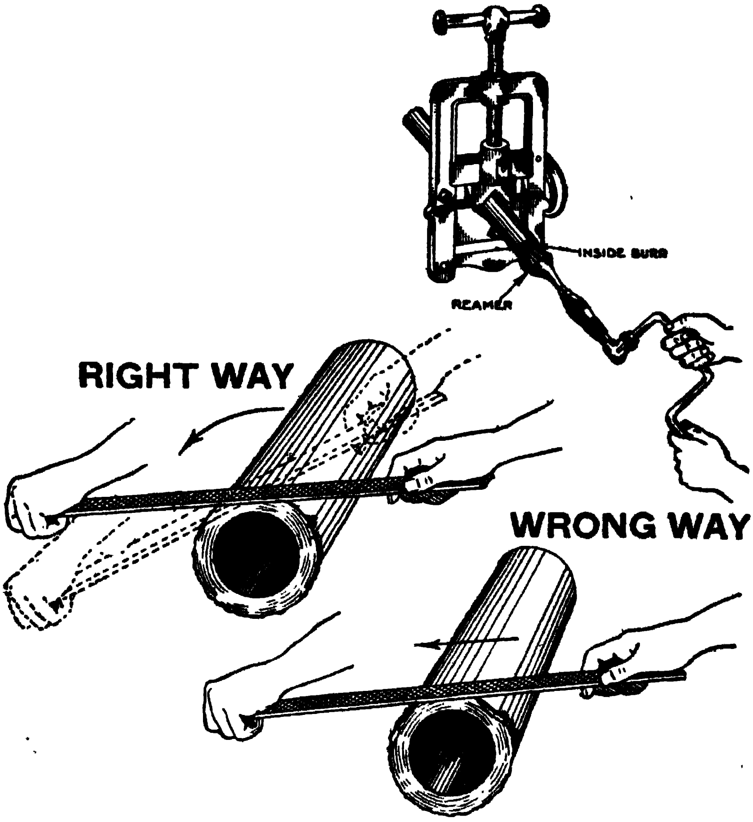
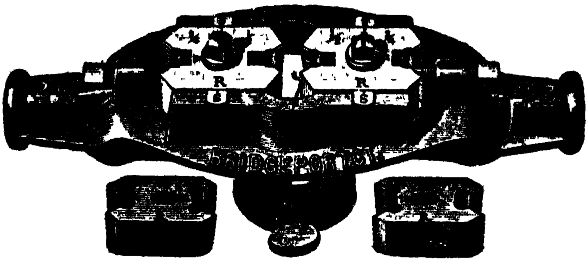


FIG. 5,490.–Method of removing burr from pipe end with brace and a burring reamer.

FIGS. 5,491 and 5,492.—*Right* and *wrong* way of removing the shoulder left on pipe after cutting with a pipe cutter. Obviously at each stroke, the file should be given a turning motion as indicated by the arrow and dotted position in figure 5,491 removing the excess metal through an arc of the circumference. The position of pipe is changed in the vise from time to time, till the excess metal is removed all around the pipe. When the operation is done as in fig. 5,492, by moving the file in a straight line, it will result in a series of flat

Pipe Threading.—Having cut the pipe to proper length, filed off the outer shoulder and reamed out the burr, it is now ready for the threading operation. The Briggs threads may be cut on the pipe ends for screwing into the fittings either by means of

1. Hand stock and dies, or
2. Pipe threading machines.



FIGS. 5,493 to 5,495.—Armstrong *adjustable* pipe stock and dies for *double* ended dies. Each pair of dies, as shown, has one size thread at one end and another size at the other. Thus the two dies in the stock are in position for cutting ½-inch thread and by reversing them they will cut ¾-inch thread. The cut shows plainly the reference marks which must register with each other in adjusting the dies to standard size by means of the end set screws.

The hand stock and dies being portable, are generally used for small jobs, especially for threading pipe of the smaller sizes, although there are some geared forms suitable for large work without undue physical effort; the threading machines are for use in shops where a large amount of threading is done.

In cutting a thread use plenty of oil in starting and cutting the thread.

In starting, press the dies firmly against the pipe end until they "take hold." After a few turns blow out the chips and apply more oil. This

NOTE.—*There is a great variety of stocks and dies*, the types shown in figs. 5,493 to 5,495 being well adapted to ordinary work. It will be noted that the stock is *adjustable*, that is, the dies may be moved in or out to vary the diameter of the thread, thus loose or tight fit threads may be cut.

should be done two or three times before completing the cut. When complete blow out chips as clean as possible and back off the die. Avoid the frequent reversals usually made by some pipe fitters.

For lubrication, lard will be found preferable to oil. Apply the lard to the pipe end with a brush. In cutting the thread, the heat generated will melt the lard which will flow to the cutting edge of the die giving continuous lubrication instead of spasmodic flooding as is the case when using oil.*

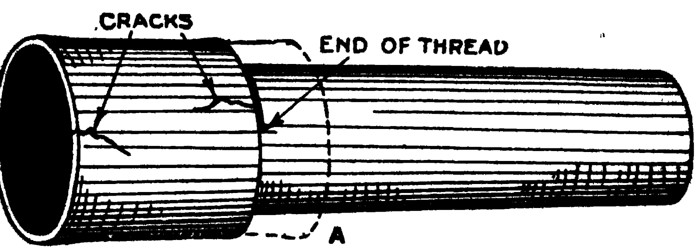


FIG. 5,496.—Makeshift nipple holder as used by some pipe fitters. *It consists of* a short length of pipe having a coupling on one end. *In operation,* one end of the nipple is screwed into the coupling, and the die applied to the other end. In doing this the turning force necessary to cut the thread being considerable, the coupling will be forced on the pipe (beyond the thread) to some position indicated by the dotted line *A*, straining the coupling beyond its elastic limit and probably cracking same as indicated. The nipple thus made is removed from the coupling and die by the aid of a Stillson wrench and some profanity. The coupling now being in a condition known to a certain class of workmen as "*on the hog,*" it is replaced by a new one each time a nipple is to be cut. *In sending in the bill,* the waste of time and couplings are of no consequence to an unscrupulous mechanic, for these items are charged to the customer along with such things as candles, waste, charcoal, oil, matches, etc.—*at a very HANDSOME profit.*

Threading Nipples.—The pipe fitter usually makes any nipples required, but usually better nipples (especially the close and short variety) can be obtained from the supply house at less cost.

No pipe fitter deserving to be called such will attempt to cut nipples without a proper nipple holder, although some plumbers and some nondescripts are often guilty of such practice when working by the day instead of by the job.

*NOTE.—The author is indebted to Mr. Harbison, thread expert of the National Tube Co., for this suggestion.

The ordinary method of cutting nipples as indulged in by some plumbers and others as shown in fig. 5,496 *for lack of proper tools, is very unsatisfactory.*

In emergency, the proper way to cut a nipple with such a makeshift holder so as not to split the coupling is to use adjustable dies, as, for instance, the Armstrong pattern (figs. 5,493 to 5,495). First take a very light cut, then adjust dies and take one or more additional cuts to finish. The cost of a properly made nipple holder, such as shown in fig. 5,497, is so small that it should be included in every pipe threading outfit

Calculation of Offsets.—In pipe fitting the term *offset* may

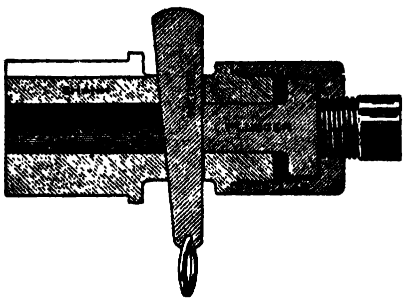


Fig. 5,497.—Jarecki nipple holder for threading close and short nipples.

be defined as *a change of direction* (*other than* 90°) *in a pipe bringing one part out of, but parallel with the line of another.*

Thus in fig. 5,498, it is necessary to change the position of pipe line L, at A, to same parallel position as that of line F, because of some obstruction such as the wall E, of the building. When the two lines L and F, are to be piped with elbows or bends other than 90°, the pipe fitter encounters a problem of finding the length of the pipe H, connecting the two elbows A and C, also to determine the distance BC, in order to fix the point A, so that the two elbows A and C, will be in alignment.

Of course in the triangle ABC, the length of pipe AC, and either offset (AB or BC that may be required) are quickly calculated by solving the triangle ABC, for the desired member, but this involves taking the square

root which is not understood by every mechanic, hence an easier method will be given for those having limited knowledge of mathematics.

1st Method.

In the triangle ABC

$$\overline{AC}^2 = \overline{AB}^2 + \overline{BC}^2$$

from which

$$AC = \sqrt{\overline{AB}^2 + \overline{BC}^2}$$

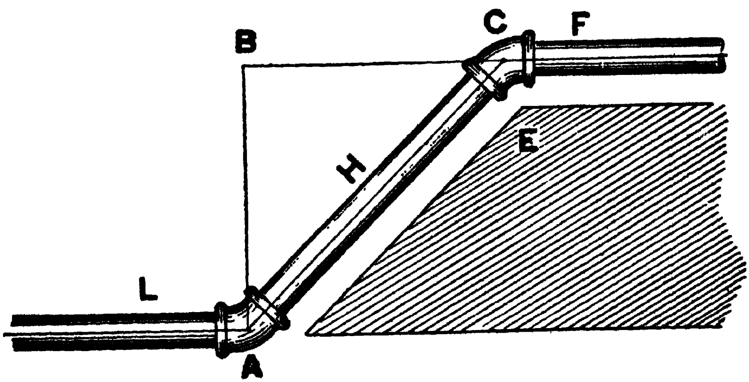


FIG. 5,498.—Pipe line connected with 45° elbows illustrating offsets and method of finding length of connecting pipe H.

Example.—If in fig. 5,498, the distance between pipe lines L and F be 20 ins. (offset AB) what length of pipe H, is required to connect with the 45° elbows A and C?

When 45° elbows are used both offsets are equal, hence substituting in equation (1)

$$AC = \sqrt{20^2 + 20^2} = \sqrt{800} = 28.28 \text{ ins.}$$

2nd Method.

The following rule will be found convenient for calculating 45° elbows.

Rule.—*For each inch of offset add $\frac{53}{128}$ of an inch and the result will be the length between centers of the elbows.*

Example.—Calculate length AC (center of elbows) of the preceding example by the above rule.

$$20\times\frac{53}{128}=\frac{1,060}{128}=8\tfrac{9}{32}$$

adding this to the offset

$$20+8\tfrac{9}{32}=28\tfrac{9}{32}$$

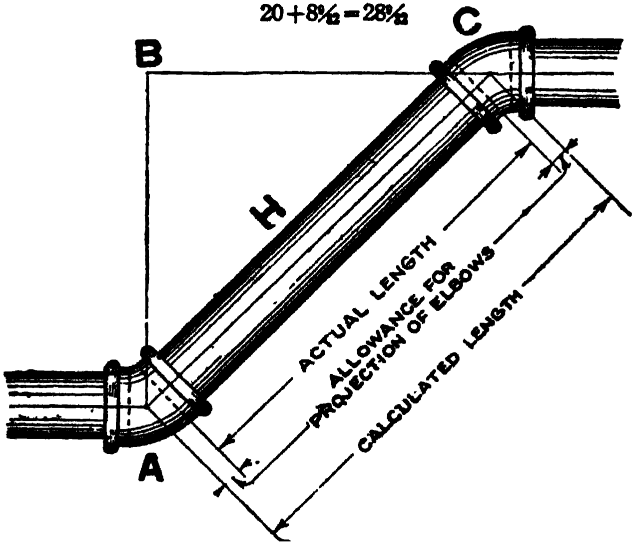


FIG. 5,499.—Calculated and actual length of connecting conduit with elbows other than 90°. Note carefully the allowances or deduction from calculated length for projection of elbows.

This is the calculated length, and to obtain the actual length, deduct the allowance for projection of the elbows as shown in fig. 5,499.

3rd Method.

This is for angles other than 45°, such as 22½, 11¼, etc., which the pipe fitter often encounters. For such, the distance between centers can easily be found by use of the following table of constants.

Elbow Constants

Angle of Elbow	Elbow Centers AC	Offset AB
60°	1.15	.58
45°	1.41	1.00
30°	2.00	1.73
22½°	2.61	2.41
11¼°	5.12	5.02
5⅝°	10.20	10.15

NOTE.—In the above table the letters refer to fig. 5,500.

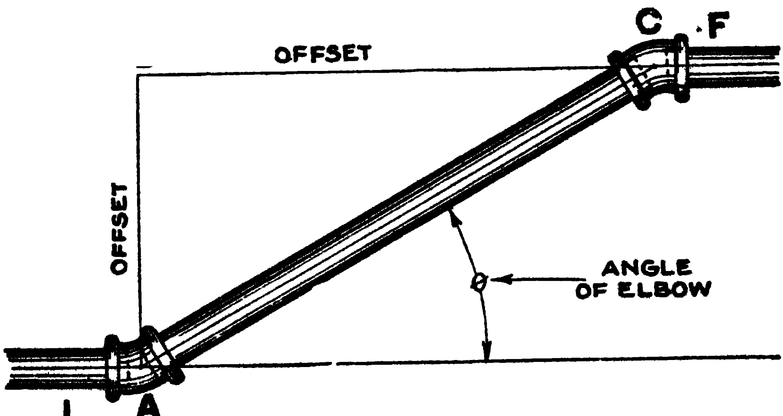


FIG. 5,500.—Diagram for elbow constants.

In using the above table, use is made of the rule which follows:

Rule.—*To find length between centers multiply offset by constant for the angle used.*

That is, referring to fig. 5.500.

AC = offset AB × constant for AC............(1)
BC = offset AB × constant for AB............(2)

Example.—If in fig. 5,500, the distance between pipe lines L and F, (offset AB) be 20 ins., what is length of offset BC, and distance AC, between center of elbows, for 22½° elbows?

In the table constant for AB, with 22½° elbow is 2.41. Substituting values in equation (2)

$$BC = 20 \times 2.41 = 48.2 \text{ ins.}$$

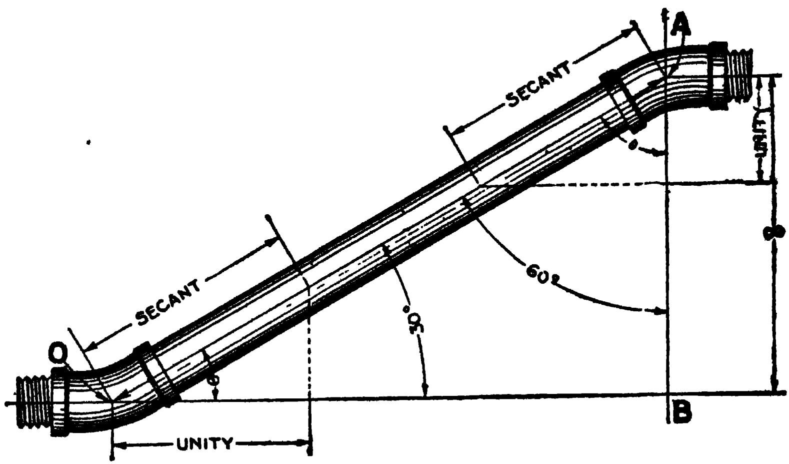


Fig. 5,501.—Two parallel conduit lines with 30° bends illustrating use of natural trigonometrical functions in finding offset and length of connecting pipe.

For distance AC, between centers of elbows, find in table constant for AC = 2.61. Substituting in equation (1)

$$AC = 20 \times 2.61 = 52.2 \text{ ins.}$$

4th Method.

Offsets may be calculated by aid of trigonometry as illustrated by the following example.

Example.—In fig. 5,501, two pipe lines 8 ins. apart are to be connected with 30° elbows. What is the length of the offset OB and connecting pipe OA?

From the accompanying table, tan. 60 = 1.732; length offset OB = 1.732 × 8 = 13.86 ins.

Again, from table sec. 60 = 2; length connecting pipe OA = 8 × 2 = 16 ins.

Natural Trigonometrical Functions

Degree	Sine	Cosine	Tangent	Secant	Degree	Sine	Cosine	Tangent	Secant
0	.00000	1.0000	.00000	1 0000	46	.7193	.6947	1.0355	1.4395
1	.01745	.9998	.01745	1.0001	47	.7314	.6820	1.0724	1.4663
2	.03490	.9994	.03492	1.0006	48	.7431	.6691	1.1106	1.4945
3	.05234	.9986	.05241	1.0014	49	.7547	.6561	1.1504	1.5242
4	.06976	.9976	.06993	1 0024	50	.7660	.6428	1.1918	1.5557
5	.08716	.9962	.08749	1 0038	51	.7771	.6293	1.2349	1.5890
6	.10453	.9945	.10510	1.0055	52	.7880	.6157	1.2799	1.6243
7	.12187	.9925	.12278	1 0075	53	.7986	.6018	1.3270	1 6616
8	.1392	.9903	.1405	1.0095	54	.8090	.5878	1.3764	1.7013
9	.1564	.9877	.1584	1.0125	55	.8192	.5736	1.4281	1.7434
10	.1736	.9848	.1763	1.0154	56	.8290	.5592	1.4826	1.7883
11	.1908	.9816	.1944	1.0187	57	.8387	.5446	1.5399	1 8361
12	.2079	.9781	.2126	1.0223	58	.8480	.5299	1.6003	1.8871
13	.2250	.9744	.2309	1.0263	59	.8572	.5150	1.6643	1.9416
14	.2419	.9703	.2493	1.0306	60	.8660	.5000	1.7321	2 0000
15	.2588	.9659	.2679	1.0353	61	.8746	.4848	1 8040	2.0627
16	.2756	.9613	.2867	1 0403	62	.8829	.4695	1 8807	2 1300
17	.2924	.9563	.3057	1.0457	63	.8910	.4540	1.9626	2.2027
18	.3090	.9511	.3249	1.0515	64	.8988	.4384	2 0503	2.2812
19	.3256	.9455	.3443	1.0576	65	.9063	.4226	2.1445	2.3662
20	.3420	.9397	.3640	1.0642	66	.9135	.4067	2 2460	2.4586
21	.3584	.9336	.3839	1 0711	67	.9205	.3907	2.3559	2.5593
22	.3746	.9272	.4040	1 0785	68	.9272	.3746	2.4751	2.6695
23	.3907	.9205	.4245	1 0864	69	.9336	.3584	2.6051	2.7904
24	.4067	.9135	.4452	1.0946	70	.9397	.3420	2 7475	2.9238
25	.4226	.9063	.4663	1.1034	71	.9455	.3256	2.9042	3.0715
26	.4384	.8988	.4877	1.1126	72	.9511	.3090	3.0777	3.2361
27	.4540	.8910	.5095	1.1223	73	.9563	.2924	3.2709	3 4203
28	.4695	.8829	.5317	1.1326	74	.9613	.2756	3 4874	3.6279
29	.4848	.8746	.5543	1.1433	75	.9659	.2588	3.7321	3.8637
30	.5000	.8660	.5774	1.1547	76	.9703	.2419	4 0108	4.1336
31	.5150	.8572	.6009	1.1666	77	.9744	.2250	4.3315	4.4454
32	.5299	.8480	.6249	1.1792	78	.9781	.2079	4.7046	4.8097
33	.5446	.8387	.6494	1.1924	79	.9816	.1908	5.1446	5.2408
34	.5592	.8290	.6745	1.2062	80	.9848	.1736	5.6713	5.7588
35	.5736	.8192	.7002	1.2208	81	.9877	.1564	6.3138	6.3924
36	.5878	.8090	.7265	1.2361	82	.9903	.1392	7.1154	7.1853
37	.6018	.7986	.7536	1.2521	83	.9925	.12187	8.1443	8.2055
38	.6157	.7880	.7813	1.2690	84	.9945	.10453	9.5144	9.5668
39	.6293	.7771	.8098	1:2867	85	.9962	.08716	11.4301	11.474
40	.6428	.7660	.8391	1.3054	86	.9976	.06976	14.3007	14.335
41	.6561	.7547	.8693	1.3250	87	.9986	.05234	19.0811	19.107
42	.6691	.7431	.9004	1.3456	88	.9994	.03490	28 6363	28.654
43	.6820	.7314	.9325	1.3673	89	.9998	.01745	57.2900	57.299
44	.6947	.7193	.9657	1.3902	90	1.0000	Inf.	Inf.	Inf.
45	.7071	.7071	1 0000	1 4142		—	—	—	—

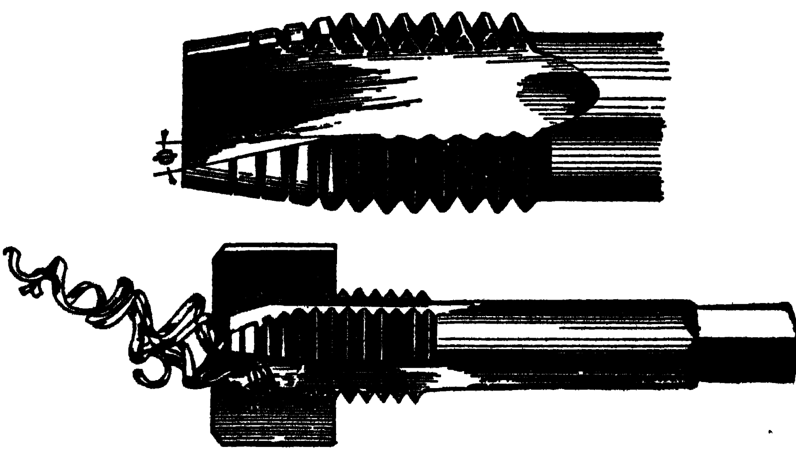
Pipe Tapping.—Frequently in pipe fitting, it is necessary to cut internal threads on pipes, as in making pipe headers, lubricator connections, etc. This is called *tapping*, and involves:

1. Drilling holes to correct diameter;
2. Sometimes reaming;
3. Cutting the internal threads by means of a *tap*.

It is first necessary to know what size hole is required for the size of tap.

The table on page 3,297 gives drill sizes which permit of direct tapping without reaming the hole beforehand.

The Briggs standard is the standard used in the United States.



FIGS. 5,502 and 5,503.—Greenfield "gun" tap and character of its cut. *This tap* differs from ordinary taps in that the cutting edges, are ground at an angle ϕ, to the axis of the tap. This causes the tap to cut with a shearing motion, that is, with the least resistance to the thrust. The angle of the flutes deflects the chips so that they curl out and ahead of the tap and do not collect and break up in the flutes.

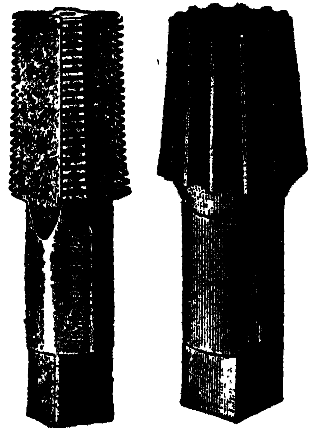
Drill Sizes for Briggs Standard Pipe Taps

(For direct tapping without reaming)

Size of pipe	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
Size of drill	11/32	7/16	9/16	45/64	59/64	1 5/32	1 31/64	1 47/64	2 13/64	2 5/8	3 1/4	3 47/64	4 13/64

Drill Sizes for Pipe Taps

Size Tap Inches	BRIGGS STANDARD		BRITISH (Whitworth) STANDARD	
	Thread	Drill	Thread	Drill
1/8	27	21/64	28	5/16
1/4	18	27/64	19	7/16
3/8	18	9/16	19	9/16
1/2	14	11/16	14	23/32
5/8	....	....	14	025/32
3/4	14	29/32	14	29/32
7/8	....	..	14	1 1/16
1	11 1/2	1 1/8	11	1 5/32
1 1/4	11 1/2	1 15/32	11	1 1/2
1 1/2	11 1/2	1 23/32	11	1 23/32
1 3/4	....	....	11	1 31/32
2	11 1/2	2 3/16	11	2 3/16
2 1/4	....	... .	11	2 13/32
2 1/2	8	2 9/16	11	2 21/32
2 3/4	. ..	....	11	3 1/16
3	8	3 3/16	11	3 5/32
3 1/4	....	....	11	3 1/2
3 1/2	8	3 11/16	11	3 3/4
3 3/4	....	....	11	4
4	8	4 3/16	11	4 1/4
4 1/2	8	4 11/16	11	4 3/4
5	8	5 1/4	11	5 1/4
5 1/2	....	....	11	5 3/4
6	8	6 5/16	11	6 1/4
7	8	7 5/16	11	7 5/16
8	8	8 5/16	11	8 5/16
9	8	9 5/16	11	9 5/16
10	8	10 5/16	11	10 5/16



Figs. 5,504 and 5,505.—Pipe tap and pipe reamer. Do not use a *straight* tap by mistake for a taper tap

The table at the left (by Greenfield), gives drill sizes for pipe taps for both the Briggs or American Standard, and Whitworth, or British Standard.

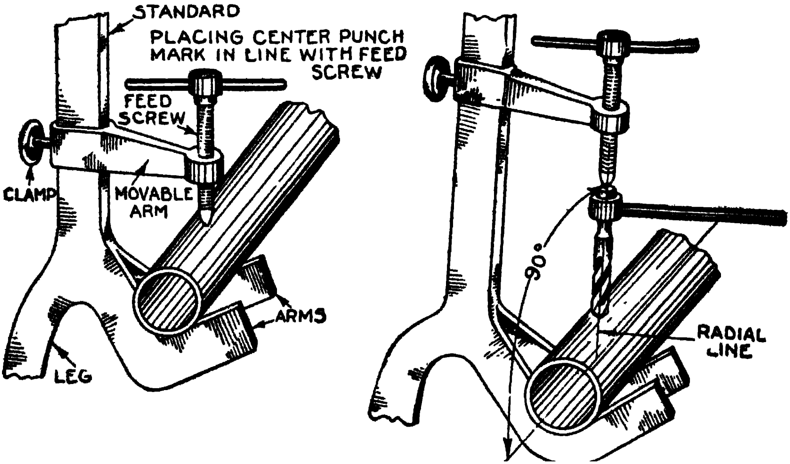
Figs. 5,504 and 5,505 show a pipe tap and reamer.

Since the thread is

tapered, it might be inferred that after drilling, the hole should be reamed with a tapered pipe reamer, but this is not necessary if the size of the drill be increased slightly.

In drilling a pipe for tapping, care should be taken that the drill be guided in a radial direction and perpendicular to the pipe axis.

Fig. 5,506 shows a pipe drilling crow designed for the purpose and fig.



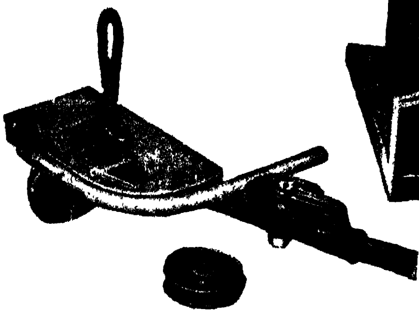
FIGS. 5,506 and 5,507.—Pipe drilling crow and method of using. *The illustrations* need no explanation.

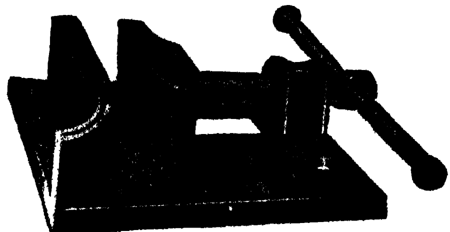
5,507, pipe and drill in position. Of course where such device is not at hand, various makeshifts have to be resorted to.

Conduit Bending.—Instead of using fittings such as elbows, tees, Ys, etc., turns in the direction of the conduit are usually made by bending.

NOTE.—*It is highly important that threading dies* be kept in good working condition, for even with uniform pipe it is difficult to secure good threads if the chasers of a die be lacking in proper lip angle, clearance in lead or thread, have broken teeth, or if the die be lacking in chip space, sufficient number of chasers, etc.

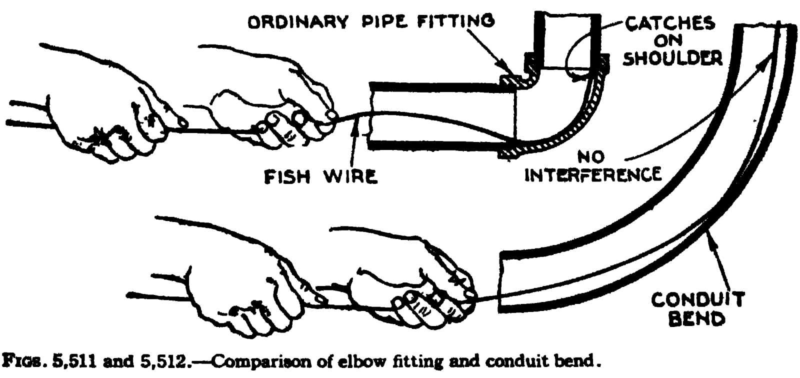
To comply with the Code, *the radius of the curve of the inner edge of any bend shall not be less than six times the internal diameter of the conduit.*





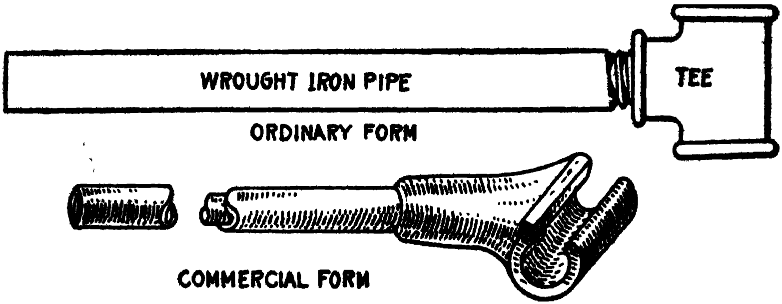
FIGS. 5,508 and 5,509.—Austin combination pipe vise and form bender. Without removing conduit from the vise it can be cut, threaded. reamed and bent. The tempered jaws can be replaced when worn out.

FIG. 5,510.—Austin conduit elbow former for ½ and ¾ conduit.



FIGS. 5,511 and 5,512.—Comparison of elbow fitting and conduit bend.

NOTE.—***For cutting threads on regular Bessemer steel pipe,*** each chaser should have a lip angle of 15 to 20 degrees; for open hearth, at least 25 degrees. By grinding a slightly curved lip of this angle, an easy cutting action is given to the chaser, similar to that of a properly ground lathe tool, and the effect of pushing the metal off instead of cutting it is avoided. If there be a square corner or shoulder at the top of the lip, this should be removed, as it forms a place where chips may lodge and pile up, resulting in torn threads and unnecessary friction and often in condemnation of the thread by the inspector in charge. Clearance is the space between the pipe threads and the teeth of the chaser.



FIGS. 5,513 and 5,514.—Home made and commercial forms of hickey. The home made hickey consists of a piece of one inch steam pipe about three feet long with a one inch cast iron tee screwed onto one end of the pipe.

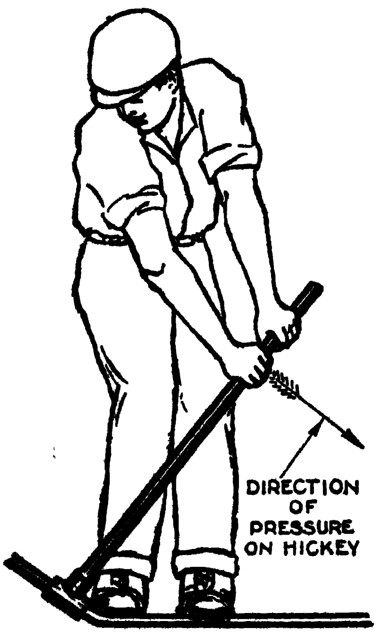


FIG. 5,515.—Method of bending conduit with a hickey. *In bending*, the conduit to be bent is placed on the floor and the tee slipped over it. The workman then places one foot on the conduit close to the tee, and pulls the handle of the bender toward him. As the bending progresses, the workman should take care to continually move the bender away from himself, to prevent buckling of the conduit.

This requirement precludes even the use of long sweep fittings. The reason for this is because the Code requires the conduit ***to be installed as a complete system without the wires.*** Accordingly, too much force would be required to pull the wires around bends sharper than specified which might injure the wire insulation. Moreover, if an ordinary pipe fitting were used instead of a conduit fitting, there would be difficulty in *fishing*, because the end of the fish wire would catch against the shoulder presented by the end of the conduit at the screwed joint as in fig. 5,511. This is avoided by bending the conduit as in fig. 5,512.

Various types of tools known as conduit benders are used to bend conduit. They may be classified as

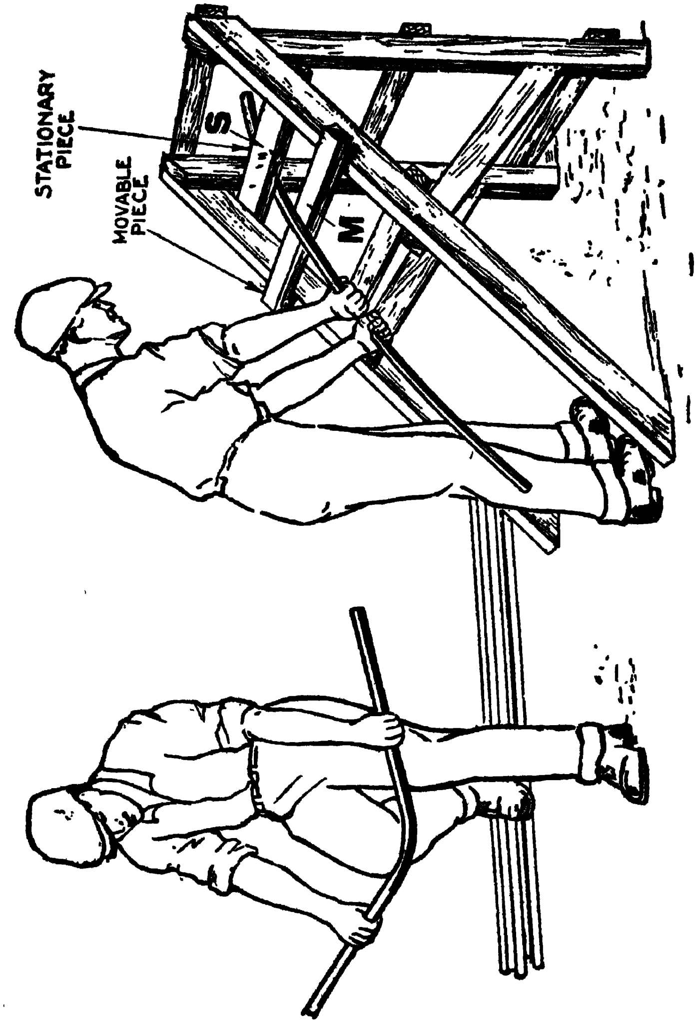


FIG. 5,516.—Method of bending small size conduit over the knee. FIG. 5,517.—Method of bending conduit on a rack.

1. Hickeys;
2. Racks;
3. Bending block and pins;
4. Geared benders;
5. Form benders;
6. Roller benders;
7. Inertia benders.

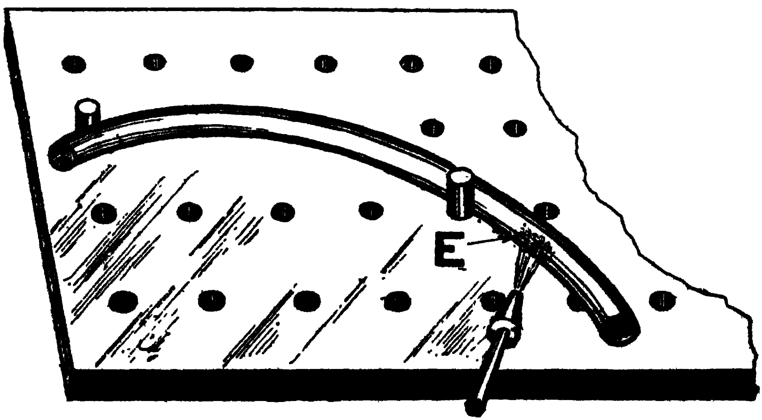


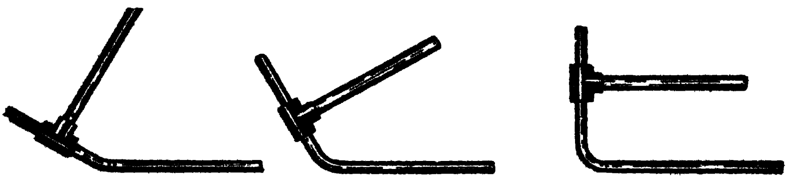
FIG. 5,518.—Method of bending with bending block and pins. *In bending*, the pipe is heated in a small spot at a time on the inside of the bend, as shown by the shaded portion at E. If the heat extend around the outside of the pipe, this should be chilled with water immediately before bending, the object being to keep the outside cold to prevent flattening the pipe while the pressure of the bending causes the inside to upset and so furnishes the shorter radius for the inside. Only a very small portion of the pipe can be heated at a time and should the pressure cause the inside to start to kink at any point, that place must be immediately chilled with water, and the bending continued further along. On account of the constant shifting of the heat on a very small portion at a time, the use of an oil torch for heating is a great advantage, as it saves carrying the pipe to and from a forge, but the latter can be used if necessary.

A hickey is a form of hand bender consisting of a long lever having at one end a slot at right angles, which fits over and grips the conduit when pressure is brought on the lever or handle to bend the conduit. Fig. 5,513 shows a home made hickey constructed out of a length of pipe and a tee. A commercial form of hickey is shown in fig. 5,514. The method of using a hickey is illustrated in fig. 5,515.

A rack is any kind of a built up contrivance which provides two rigid

points for engaging the conduit so that it will be held as in a vise, when pressure is applied to the conduit in bending. Fig. 5,517 shows one form of rack. In using this device the movable arm piece **M**, may be adjusted with respect to **S**, most suitable to the size conduit and radius of the required bend.

Bending with a bending block and pins is a simple method but requires a careful workman to get a smooth job, and though adaptable to the largest sizes of pipe, may require a tedious amount of work. Two pins are required for the necessary leverage to pull the pipe around. The plate is desirable for keeping the bend in a true plane. and to form a rigid support or anchorage for the pins. In the former method are substituted the



FIGS. 5,519 to 5,521.—Correct method of making a quarter bend with a hickey. The pipe should be marked at the place where the bend is to be made, grasp pipe with hickey and raise pipe from floor a few inches, shift hickey and bend conduit a little more; keep shifting hickey until the proper bend is made. *To make an offset:* Stand hickey on floor in an upright position with the bending part up, insert pipe into opening and pull down on the pipe, using the length of the pipe as a leverage, having made the bend as far as desired, turn the bend up and repeat as above.

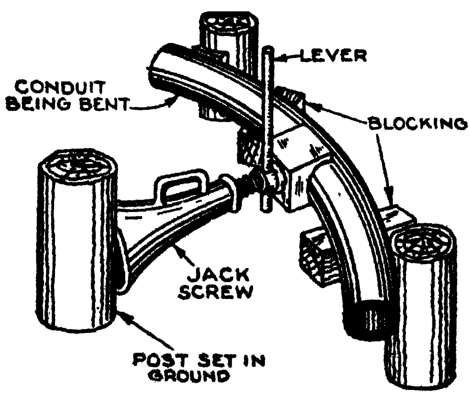


FIG. 5,522.—Method of bending with jack and post support, illustrating one form of geared bender

parts **M** and **S** for the pins. This method of bending is shown in fig. 5,517.

Where a very heavy pressure is required as in bending large size conduit, some method of multiplying the force exerted by hand is necessary

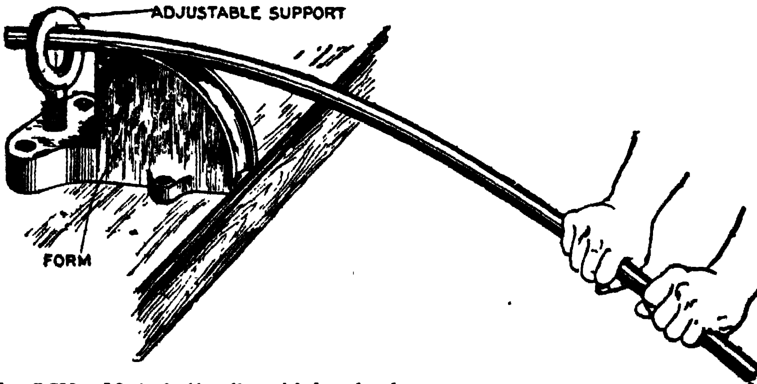


FIG. 5,523 —Method of bending with form bender.

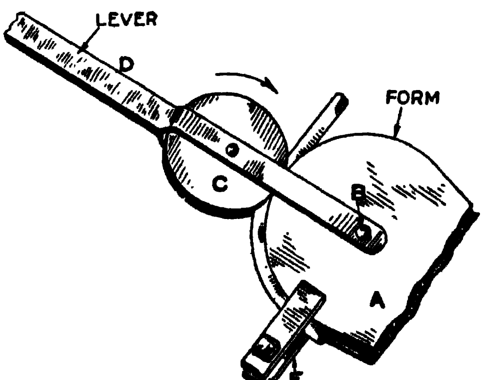
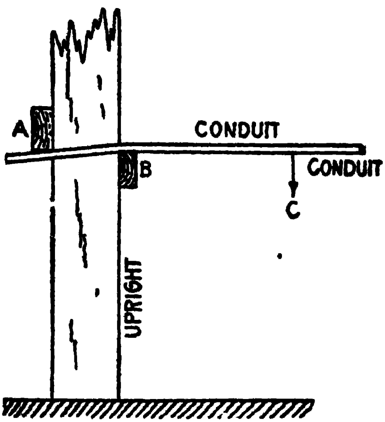
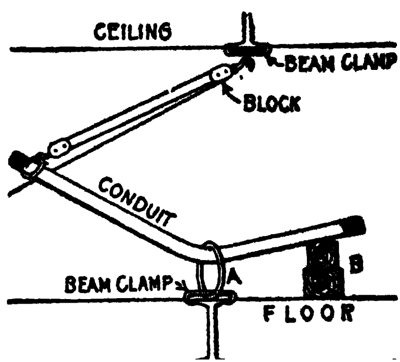


FIG. 5,524—Method of bending with a roller bender. *It consists of* a circular form A, with bending pulley C, radially hinged at B. Owing to the considerable effort required to bend pipe, the part A, must be very securely fastened to some rigid support. *In bending,* the lever is brought over to the projection E, and pipe placed in position. Then the lever is forced around in the direction from E, toward the straight pipe thus bending the pipe to conform with the bending form. The pipe, of course, must first be filled with sand and capped to prevent buckling, and also heated if the bending radius be small enough to require

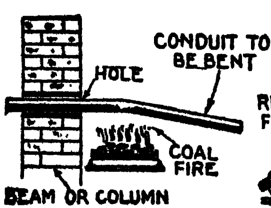
as by utilizing a jack or differential chain gear. This method is shown in fig. 5,522 and of course there are many ways of rigging up the necessary supports for the conduit and jack.

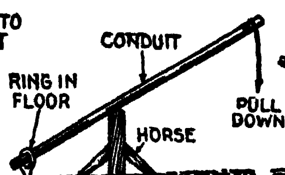
A more refined method of bending is with a form bender in which the

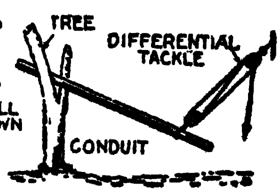




FIGS. 5,525 and 5,526.—Methods of bending large conduits. The conduit is placed under the block A and over the block B, and then bent by a downward pressure exerted at C, the conduit in the meantime being gradually advanced in the direction C, to give a curve of the required radius. The method shown in fig. 5,526, may be used wherever a ring A, can be attached to a beam or girder by means of clamps or otherwise to serve as a support.







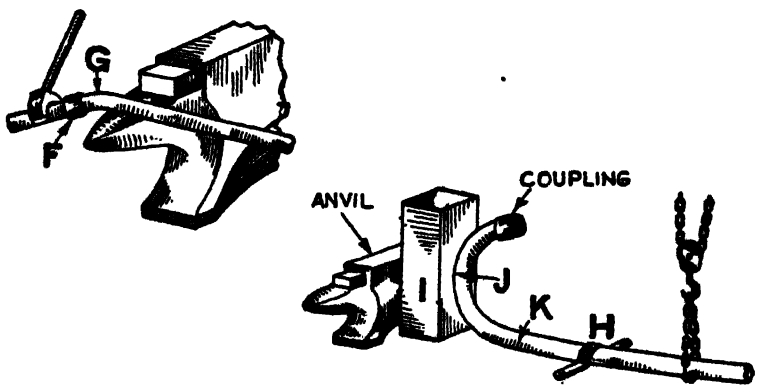
FIGS. 5,527 to 5,529.—Methods of bending large conduits. Fig. 5,527, by heating. Large conduit such as sizes above 3 inches may be bent if they be first filled with dry sand to prevent kinking and heated until cherry red over a coal fire, then bending as shown. In fig. 5,528, the conduit is inserted into a ring secured to the floor and bent over a horse by pulling down on the end. Another method, as shown in fig. 5,529, consists of inserting the conduit in the V of a tree and bending by attaching block and tackle, worked by team of horses, or preferably by a differential tackle as shown.

conduit is form shaped to the right curve by the curve of the bender. The latter is shown in fig. 5,523 together with the method of bending.

In the roller bender, the force applied to a lever is transmitted to the conduit by a roller, which *rolls* the conduit to the required bend as shown in fig. 5,524.

A unique method of bending utilizes the force due to inertia of the pipe as it is struck against some hard surface. This method is illustrated in figs. 5,530 and 5,531.

Conduit Fittings.—By definition a conduit fitting is *a box-like device provided with projections which have female pipe*



FIGS. 5,530 and 5,531.—Inertia or anvil method of bending. In fig. 5,530 a coupling and short length of pipe are temporarily fitted on the end of the pipe, as shown at F. A short heat is taken close to the coupling at G, the pipe laid over the horn of an anvil, and with a swage and sledge the bend is started, turning the pipe over on its side if necessary to work out any kirks or flattening that may occur while this first bend is being made. The added section of pipe is then removed and a quite different method continues the work, as shown in fig. 5,531. The clamped band handle H, is now bolted on some distance back from the end, and the pipe itself is suspended by a block and sling, so that it may be easily raised and lowered as necessary, and must be hung from a support far enough above it so that it may be swung pendulum fashion through a swing of three or four feet. A heavy wood block I, for a "butting post" is leaned up against a convenient anvil or wall, as shown. A short heat is then taken on the pipe just beyond and adjoining the portion that was first bent. It is then swung like a ram against the block, and the force of the blow acting on the tangent of the first bend causes a continuation of the bending in this next section, while sufficient upsetting of the material takes place at the same time so that there is no flattening down of the outside, and the pipe holds up to its full form. This same procedure is continued for one section following another, and the pipe rolls up into form as shown at J, where in this case the shaded portion K, indicates the place where the bending is taking place.

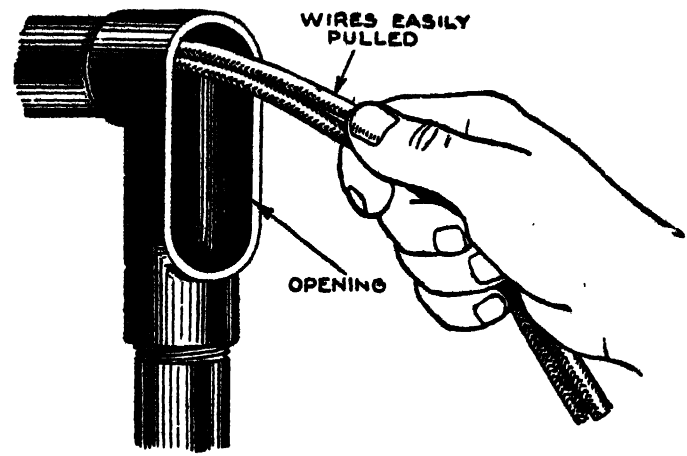


FIG. 5,532.—Conduit elbow with cover removed from opening. This makes the operation of *pulling* the wires through the conduit very easy and avoids chance of injuring the insulation if they were pulled around a sharp turn.

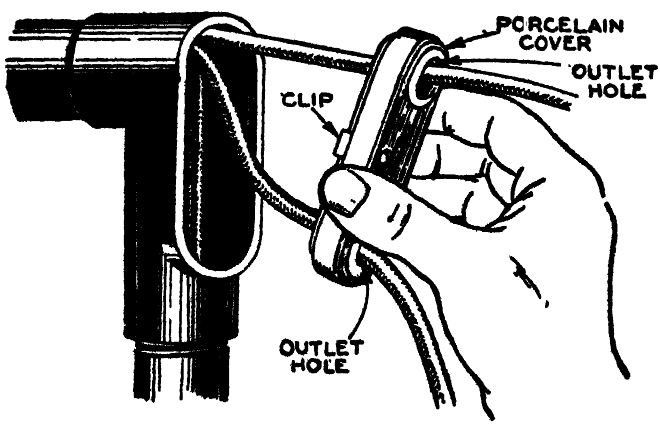


FIG. 5,533.—Conduit elbow with two wire porcelain cover showing circuit outlet provided by this type cover.

threads to which the conduit is screwed direct. They are similar to pipe fittings but modified to suit the condition for which they are intended.

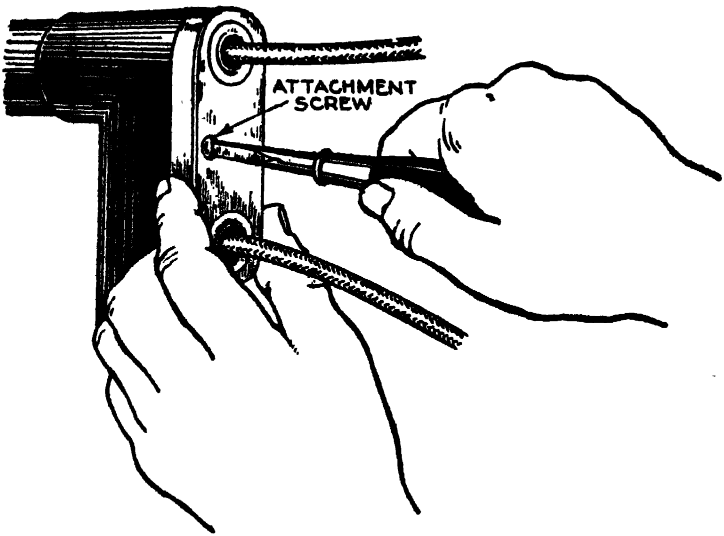
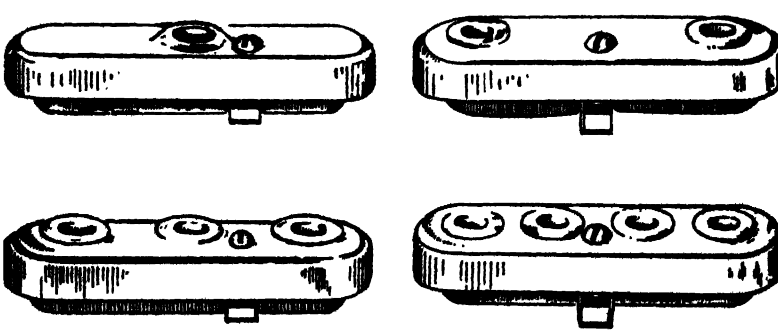
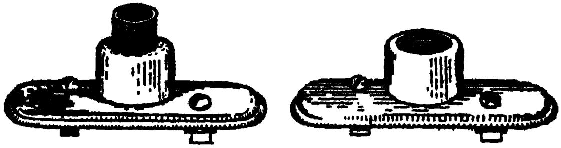


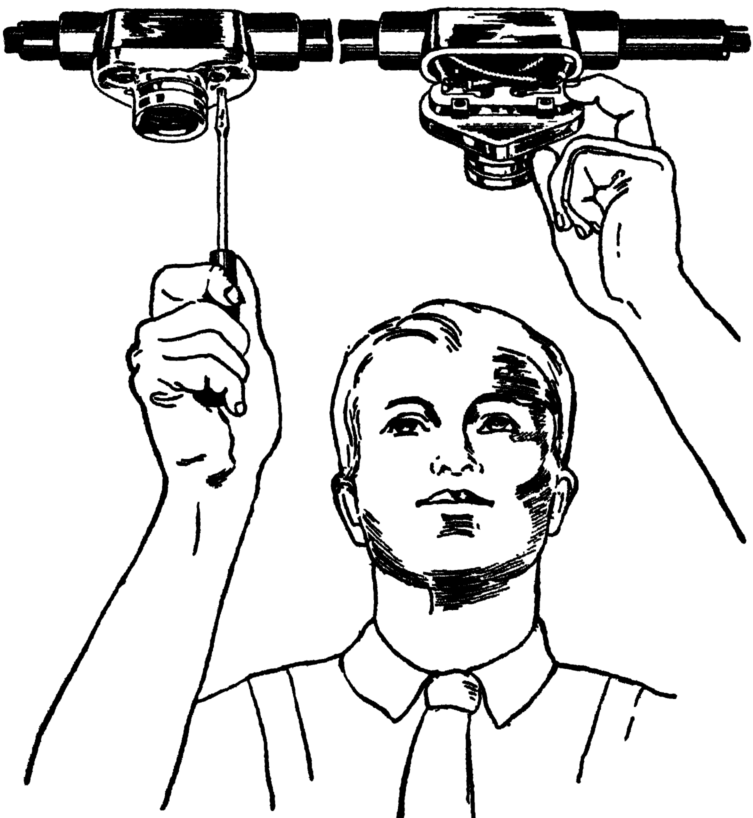
Fig. 5,534 —Conduit elbow with two wire porcelain cover showing method of attaching with screws.



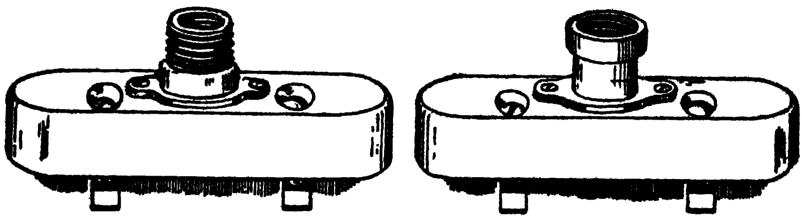
Figs. 5,535 to 5,538.—Various covers with wire holes for conduit fitting, one to four holes.



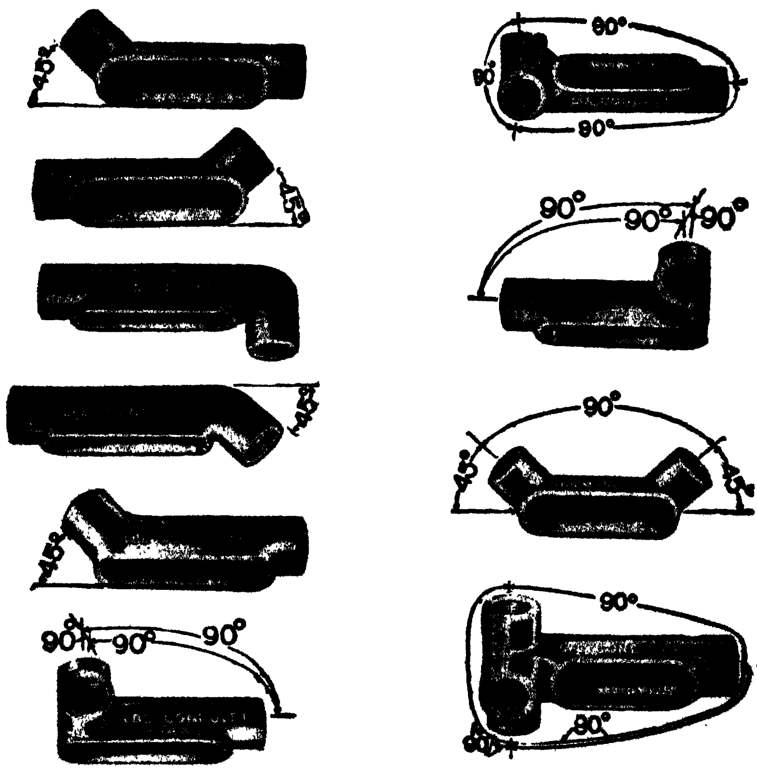
FIGS. 5,539 and 5,540.—Cast iron fixture covers. Fig. 5,539, male nipple; fig. 5,540, female nipple.



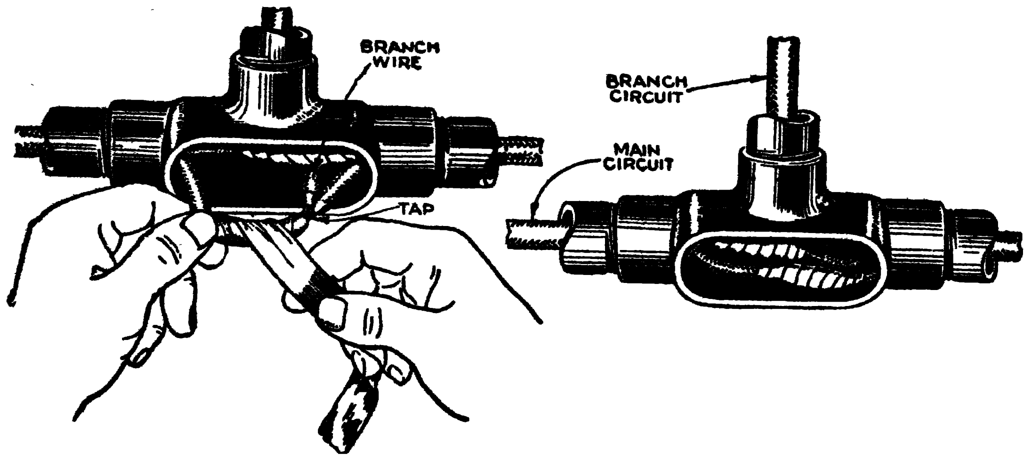
FIGS. 5,541 and 5,542.—Receptacle and cover showing method of connecting wires to base The fitting shown is an *outlet coupling*.



FIGS. 5,543 and 5,544.—Porcelain fixture covers. Fig. 5,543, male nipple; fig. 5,544, nipple.



FIGS. 5,545 to 5,554.—Crouse-Hinds conduit fittings showing some of the many types.



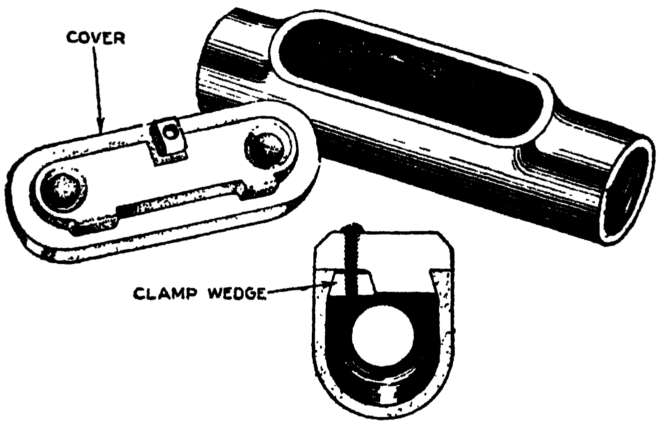
FIGS. 5,555 and 5,556.—Conduit T, showing method of tapping a branch circuit.

There is a ridiculous variety of trade names given to these fittings by the manufacturers: they are best known as *conduit fittings*.

A large multiplicity of conduit fittings are available, designed for every condition met with in wiring. It is not the purpose of the author to waste space illustrating all of them, as a study of a few of the principal types will suffice.

A conduit fitting differs from an ordinary pipe fitting principally in that it has an opening with a removable cover.

The object of thus giving access to the interior is to permit pulling the wires as shown in fig. 5,532. A conduit fitting thus serves to join two lengths of conduit, and also as a *pull box*. Moreover, its utility is increased by the various forms of cover made to fit over the opening. For instance the type cover shown in fig. 5,533 provides an outlet for a branch circuit. Fig. 5,534 shows how the various covers are fastened by screws Covers of this type are available with various numbers of holes; single hole covers are suitable for drop cord purposes.



FIGS. 5,557 to 5,559.—Crouse-Hinds, Obround pattern conduit fitting showing cover and method of fastening. The fitting shown is properly described by calling it an *outlet coupling*. The sectional view shows clearly the method of fastening the cover without resorting to internal lugs.

Another form of cover known as a receptacle cover provides connection for a light bulb. Figs. 5,541 and 5,542 show the cover.

To provide means for connecting fixtures along a conduit run, a type cover which may be called a fixture cover is used.

These are suitable for fastening fixtures either of the rigid or chain type Figs. 5,539 to 5,544 show cast iron and porcelain fixture covers.

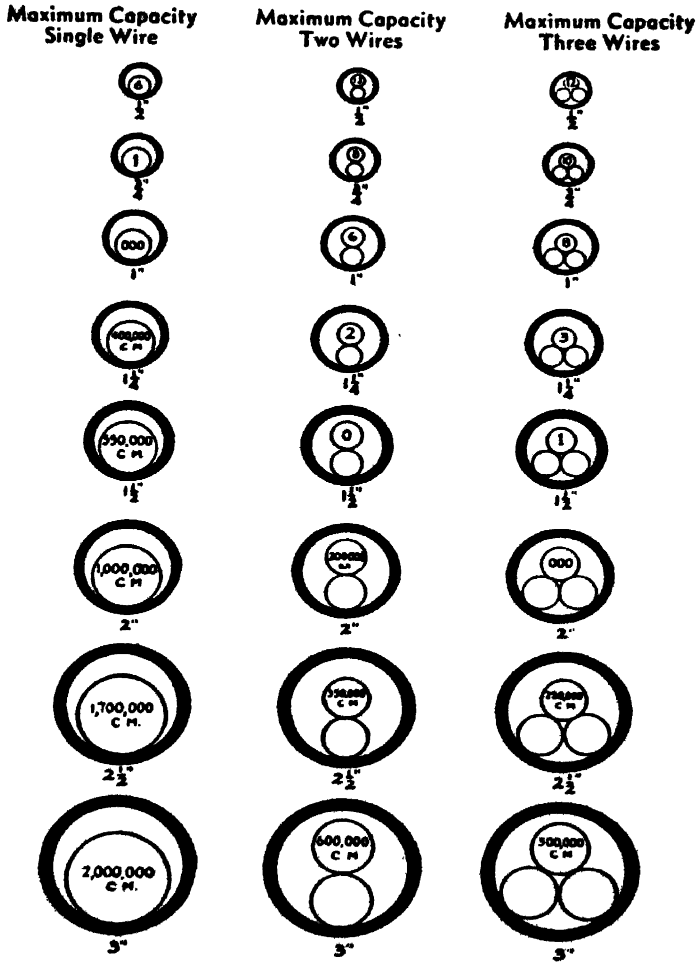
The elbow shown in fig. 5,532 is a 90° elbow. There are numerous types of 90° elbow and elbows are also made 45°. Figs. 5,545 to 5,554, will give an idea of the great variety of conduit fittings available.

An example of a T fitting, showing how a branch circuit is tapped, is illustrated in figs. 5,555 and 5,556.

TABLE 1. TWO-WIRE AND THREE-WIRE SYSTEMS.

Size of Wire	Number of Wires in One Conduit								
	1	2	3	4	5	6	7	8	9
	Minimum Size of Conduit in Inches								
No. 14	½	½	½	¾	¾	1	1	1	1
12	½	½	¾	¾	¾	1	1	1	1¼
10	½	¾	¾	1	1	1	1¼	1¼	1¼
8	½	¾	1	1	1	1¼	1¼	1¼	1¼
6	½	1	1¼	1¼	1½	1½	2	2	2
5	¾	1¼	1¼	1¼	1½	2	2	2	2
4	¾	1¼	1¼	1½	2	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1½	1½	2	2	2½	2½	2½
1	¾	1½	1½	2	2	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	2½	3	3	3½	3½	4
200000 C. M.	1¼	2	2½	2½	3	3	3½	3½	4
225000	1¼	2½	2½	3	3	3½			
250000	1¼	2½	2½	3	3	3½			
300000	1¼	2½	3	3	3½	3½			
350000	1¼	2½	3	3½	3½	4			
400000	1¼	3	3	3½	4	4			
450000	1½	3	3	3½	4	4½			
500000	1½	3	3	3½	4	4½			
550000	1½	3	3½	4	4½	5			
600000	2	3	3½	4	4½	5			
650000	2	3½	3½	4					
700000	2	3½	3½	4½					
750000	2	3½	3½	4½					
800000	2	3½	4	4½					
850000	2	3½	4	4½					
900000	2	3½	4	4½					
950000	2	4	4	5					
1000000	2	4	4	5					
1100000	2½	4	4½	6					
1200000	2½	4½	4½	6					
1250000	2½	4½	4½	6					
1300000	2½	4½	5	6					
1400000	2½	4½	5	6					
1500000	2½	4½	5	6					
1600000	2½	5	5	6					
1700000	3	5	5	6					
1750000	3	5	5	6					
1800000	3	5	6	6					
1900000	3	5	6						
2000000	3	5	6						

STANDARD SIZES OF CONDUIT
For the Installation of Wire and Cable



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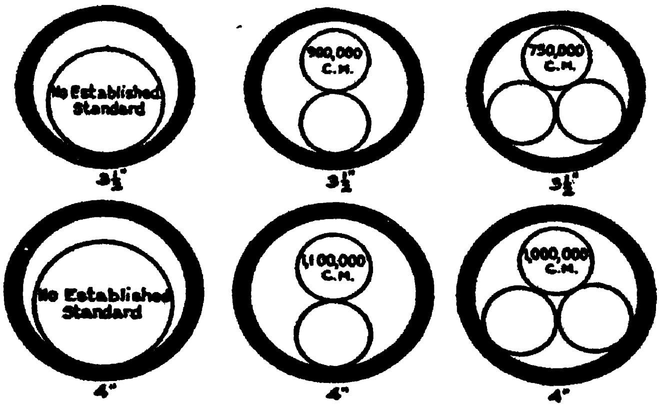


TABLE 2. THREE-CONDUCTOR CONVERTIBLE SYSTEM

Size of Wires				Size Conduit Electrical Trade Size	
two	14	and one	10	¾	Inch
"	12	"	8	¾	"
"	10	"	6	1	"
"	8	"	4	1	"
"	6	"	2	1¼	"
"	5	"	1	1¼	"
"	4	"	0	1½	"
"	3	"	00	1½	"
"	2	"	000	1½	"
"	1	"	0000	2	"
"	0	"	250000	2	"
"	00	"	350000	2½	"
"	000	"	400000	2½	"
"	0000	"	550000	3	"
"	250000	"	600000	3	"
"	300000	"	800000	3	"
"	400000	"	1000000	3½	"
"	500000	"	1250000	4	"
"	600000	"	1500000	4	"
"	700000	"	1750000	4½	"
"	800000	"	2000000	4½	"

—Continued.

TABLE 5—NUMBER OF CONDUCTORS IN CONDUIT OR TUBING

Lead-Covered Types RL and RHL—600 V.

Size AWG MCM	Number of Conductors in One Conduit or Tubing											
	Single-Conductor Cable				2-Conductor Cable				3-Conductor Cable			
	1	2	3	4	1	2	3	4	1	2	3	4
14	½	¾	¾	1	¾	1	1	1¼	¼	1¼	1½	1½
12	½	¾	¾	1	¾	1	1¼	1¼	1	1¼	1½	2
10	½	¾	1	1	¾	1¼	1¼	1½	1	1½	2	2
8	½	1	1¼	1½	1	1¼	1½	2	1	2	2	2½
6	¾	1¼	1½	1½	1¼	1½	2	2½	1¼	2½	3	3
4	¾	1¼	1½	1½	1¼	2	2½	2½	1½	3	3	3½
3	¾	1¼	1½	2	1¼	2	2½	3	1½	3	3	3½
2	1	1¼	1½	2	1¼	2	2½	3	1½	3	3½	4
1	1	1½	2	2	1½	2½	3	3½	2	3½	4	4½
0	1	2	2	2½	2	2½	3	3½	2	4	4½	5
00	1	2	2	2½	2	3	3½	4	2½	4	4½	5
000	1¼	2	2½	2½	2	3	3½	4	2½	4½	4½	6
0000	1¼	2½	2½	3	2½	3	3½	4½	3	5	6	6
250	1¼	2½	3	3	....	....	....	....	3	6	6	....
300	1½	3	3	3½	....	....	....	....	3½	6	6	....
350	1½	3	3	3½	....	....	....	....	3½	6	6	....
400	1½	3	3	3½	....	....	....	....	3½	6	6	....
500	1½	3	3½	4	....	....	....	....	4	6	....	....
600	2	3½	4	4½	....	....	....	....	....	....	....	....
700	2	4	4	5	....	....	....	....	....	....	....	....
750	2	4	4	5	....	....	....	....	....	....	....	....
800	2	4	4½	5	....	....	....	....	....	....	....	....
900	2½	4	4½	5	....	....	....	....	....	....	....	....
1000	2½	4½	4½	6	....	....	....	....	....	....	....	....
1250	3	5	5	6	....	....	....	....	....	....	....	....
1500	3	5	6	6	....	....	....	....	....	....	....	....
1750	3	6	6	....	....	....	....	....	....	....	....	....
2000	3½	6	6	....	....	....	....	....	....	....	....	....

The above sizes apply to straight runs or with nominal offsets equivalent to not more than two quarter-bends.

TEST QUESTIONS

1. *Is there any difference between rigid conduit and ordinary wrought pipe?*
2. *What are the requirements for good rigid conduit?*
3. *What knowledge must the electrician possess to install rigid conduit?*
4. *What operations are included under the term "pipe fitting"?*
5. *How should conduit be cut?*
6. *If a pipe cutter be used, what precaution should be taken?*
7. *Describe the cutting of threads on conduit.*
8. *Give various methods for the calculation of offsets.*
9. *What are the natural trigonometrical functions and how are they used in the calculation of offsets?*
10. *In making turns in a conduit line, are such fittings as elbows used?*
11. *What is the minimum radius allowed by the Code?*
12. *Mention the various methods used in bending conduit.*
13. *What is a hickey?*
14. *Describe methods of bending conduit with a form bender and with a roller bender.*
15. *What is a conduit fitting?*
16. *How does a conduit fitting differ from an ordinary pipe fitting?*
17. *What is the object of giving access to the interior of a conduit fitting?*
18. *What are the various forms of covers used on conduit fittings?*

19. *Describe a receptacle cover.*
20. *How are wires connected to the base of a receptacle cover?*
21. *Describe in detail an outlet coupling.*
22. *Describe the method of tapping a branch circuit with conduit T*
23. *What is the difference between a male nipple and a female nipple?*

CHAPTER 111

Marine Wiring Practice

The regulations for electrical installation on merchant vessels are promulgated by the *Maritime Commission, Department of Commerce, Bureau of Marine Inspection and Navigation, Federal Communications Commission* and the *American Bureau of Shipping*, and are designed in accordance with the *Marine Standard* of the *American Institute of Electrical Engineers*, the practices on which this chapter is based. It is recommended, therefore, that reference always be made to their latest specifications and requirements.

The *Bureau of Marine Inspection and Navigation* has divided vessels into the following groups:

Group No. 1

Ocean-going vessels which navigate on any ocean or the Gulf of Mexico more than 20 miles off-shore.

Group No. 2

Ocean-going vessels which navigate on any ocean or the Gulf of Mexico, but less than 20 miles off-shore.

Group No. 3

Vessels navigating Great Lakes only.

Group No. 4

Vessels navigating bays, sounds and lakes other than the Great Lakes.

Group No. 5

Vessels navigating rivers only.

Plans.—Every vessel should be provided with plans giving complete and detailed information as to circuits, wire sizes, loads, etc., for the light, power and interior communication systems. A symbol list giving the manufacturer's name, size, type, rating, catalog number or similar identification for all the equipment on the vessel should also be provided for the vessel's operating personnel.

Type of Current Used.—Distribution of electrical energy may be made either by direct or alternating current, but in present practice for electric auxiliaries direct current is usually employed. On this account, the main body of these recommendations covering auxiliaries relates to direct current installations.

Nature of Supply Source.—The following systems of distribution are recognized as standard:

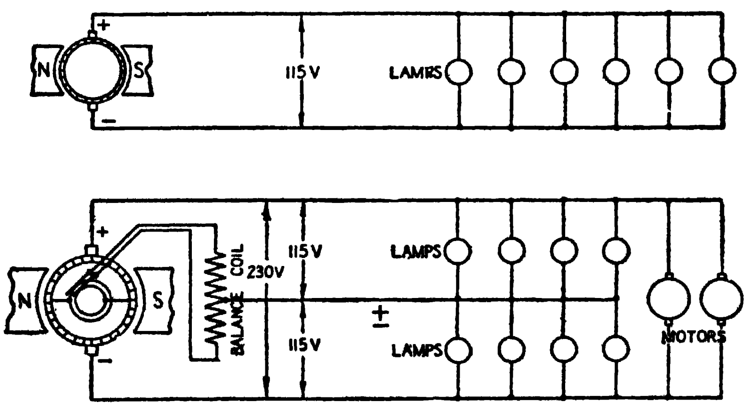
1. Two wire with direct or single phase alternating current.
2. Three wire with direct current or single phase alternating current.
3. Three phase three wire, alternating current.

Standard Voltages.—The following voltages are recognized as standard:

	Direct Current	*Alternating Current*
Lighting.....................	115 Volts	115 Volts
Power......................	115 and 230	115–220–440
Generators..................	120 and 240	120–230–450

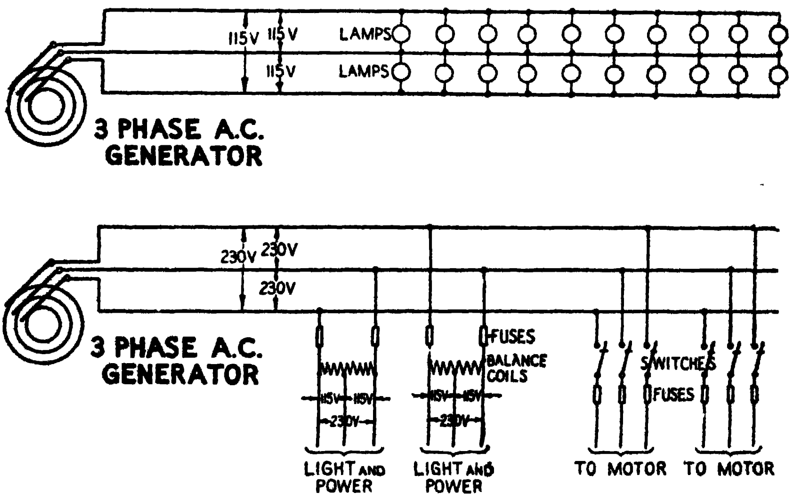
Standard Frequency.—A frequency of 60 cycles per second is recognized as a standard for all alternating-current lighting and power systems.

Selection of Voltage and Distribution System—D.C.—For vessels having little power apparatus, 120 volt generators are recommended with 115 volt light and power distribution systems. Where an appreciable amount of power apparatus is provided, 240 volt generators and 230 volt power distribution system with 115 volt lighting distribution system should be selected.



Figs. 1 and 2.—Direct current distribution systems. In the two-wire system the lamps are connected in parallel between the positive and the negative wires. The generator may be either shunt or compound wound. In fig. 2 the distribution is accomplished by means of a three wire direct current generator (Dobrowolsky system). The third wire (some times misleadingly called *neutral*) is obtained as follows: To any ordinary generator designed to give a terminal voltage equal to that between the two main wires, are added two slip rings as shown. From these slip rings two leads are brought out and connected to armature points located 180 electrical degrees apart. Collectors from the slip rings are connected to the two ends of the balance coil wound on an iron core and the middle point of this coil is finally connected to the third wire. It should be observed that in a system of this kind, it is necessary to balance the load between the two main wires and the wire leading from the balance coil as closely as possible, and the amount of unbalance should not exceed the manufacturer's specification, usually of from 10% to 15% of the total current.

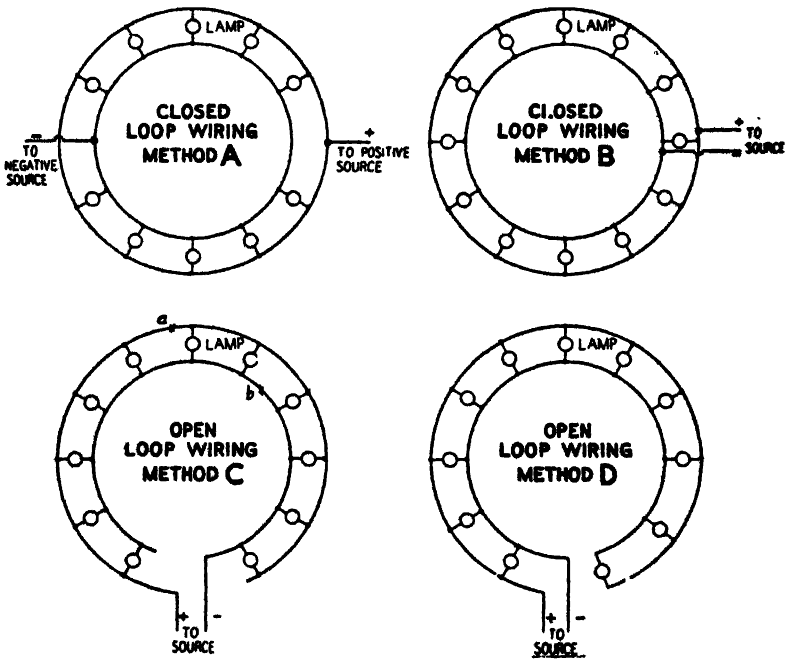
Selection of Voltage and Distribution System—A.C.—For small vessels having little power, three phase, 120 volt generators may be used with the 115 volt lighting and power distribution system. For vessels requiring considerable power apparatus, three-phase, 230 volt generators are suggested with three-phase 220 volt distribution for the power system and 115 volt single phase two wire or 115/230 volt single phase three wire



FIGS. 3 and 4.—Typical alternating current distribution systems. When it is desired to utilize 115 volts for light supply, balance coils are installed and connected as indicated. In a system of this kind, however, it is necessary that the lighting load be reasonably well balanced among the phases.

or 115 volt three phase three wire as obtained through transformers for distribution to the lighting system. Each of the three single phases should have about the same load so that currents will be about equal in each phase wire at the point where the three single phase systems are joined into one three phase system. For very large vessels with a large amount of power,

the use of 450 volt three phase generators with 440 volts or 220 volts for power distribution and 115 volts for the lighting system as described for the 230 volt generator system may be considered.



FIGS. 5A to 5D.—Showing various methods of loop-wiring. In order that all lamps in a circuit shall burn with equal brilliance at all times, it is necessary that the resistance of the circuit from the supply source to any lamp shall have a constant value, and be equal to the resistance through any other lamp. This is best accomplished in the *loop system* in which the mains are run in the form of a *closed loop*. With reference to figs. 5A and 5B, a break in either leg of the circuit will cause no break in the continuity of the circuit and all lamps will burn. It would require two breaks in any one leg to extinguish a lamp. If the loop be connected as shown in fig. 5C an analysis reveals that if a break occur at *a*, in the positive main all the lights toward the right of the open would be extinguished. Similarly a break in the negative main at *b*, would extinguish all lights to the left of the fracture.

Balancer Sets.—Balancer sets are not recommended for obtaining 120 volts from the 240 volt, two-wire direct current generators.

Rules Governing Direct Current Equipment and Installations

Installation and Location of Generator Sets.—Generating sets should be located in a well ventilated place as dry as possible. They should not be installed in the immediate proximity to water and steam piping, etc., and should be protected from dripping water, oil, etc.

Generating sets should always be installed with the shaft in the fore and aft position. There should be at least 18 inches between the set and surrounding objects to provide accessibility, and sufficient room should be provided to permit removal of the armature.

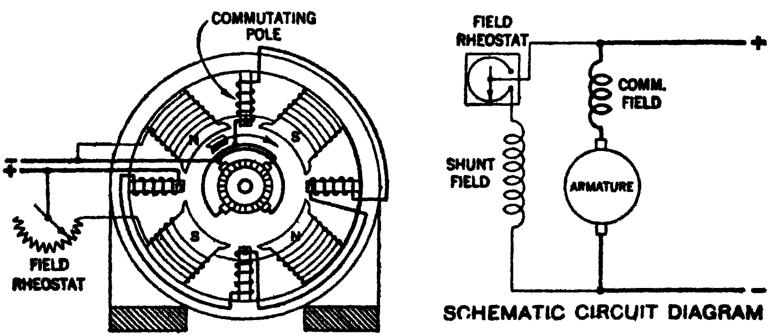
When diesel engine driven generating sets are located in deck houses, the enclosing structure should be steel or other approved fireproof material.

Generating Sets for Ship's Service—Number and Size.—In determining the capacities and number of generating sets to be provided for a vessel, careful consideration should be given to the *normal* and *maximum demands* as well as for the safe and efficient operation of the vessel when at sea and in port. The combined normal capacity of the operating generating sets should be at least equal to the *maximum peak load*, and in addition one *spare unit* should be provided. If the peak load and its duration be within the limits of the specified overload capacity of the generating sets, it is not necessary to have the combined normal capacity equal to the maximum peak load.

Generating Sets—Emergency.—In addition to the foregoing, the *Department of Commerce, Bureau of Marine Inspection and Navigation* requires the installation of a *diesel engine* driven generating set and (or) *storage batteries* located above the bulkhead deck for operating the emergency lighting and power systems.

Gasoline and semi-diesel engines are not recommended for the operation of emergency generators.

Generator Windings.—In the case of installations where the load does not fluctuate appreciably, *shunt-wound generators* without voltage regulators or the special type *compound-wound* generators may be used in lieu of *compound-wound generators*.

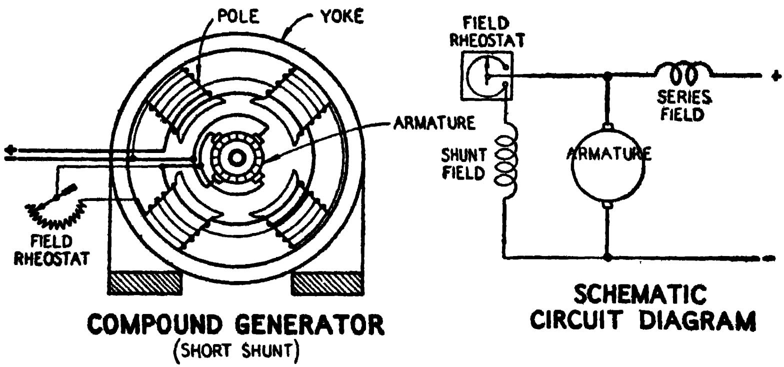


Figs. 6 and 7.—Connections of a shunt-wound generator with commutating poles and schematic diagram.

In the case of installations where the load is apt to fluctuate appreciably, *shunt-wound generators* with *voltage regulators*, or *compound-wound generators* should be used in the interest of substantially constant voltage.

Unless otherwise specified, all three-wire direct current generators should be designed for 25% unbalanced current.

In order to promote uniformity of practice for two-wire compound-wound generators, it is recommended that the series field terminal be negative.



FIGS. 8 and 9.—Connection of a compound wound generator with schematic circuit diagram.

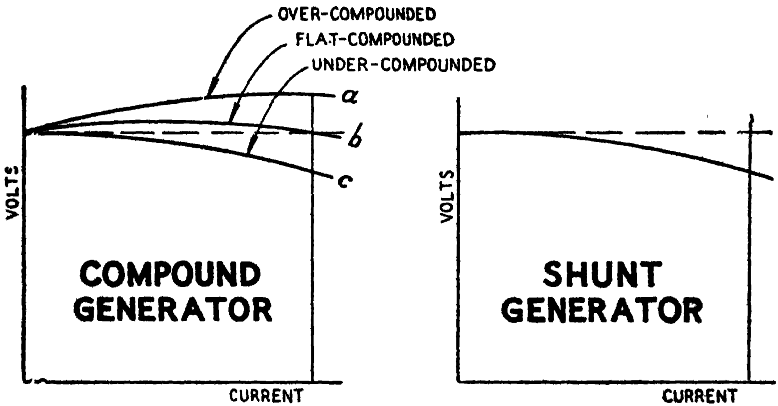
Voltage Regulation and Compounding.—When the lighting load is *not* supplied by the *main generator*, the main generator should be shunt-wound and should have an inherent voltage regulation as follows:

Shunt-wound generating sets of 150 *k.w.* and above should be designed as to speed regulation and governing of the prime mover and inherent regulation of the generator so that at full-load operating temperature there will be a rise in voltage of not over 8% when the load is gradually reduced from 100% load to 20% load, and so that there will be a drop in voltage of not more than 12% when the load is gradually increased from 20% load to 100% load, based on 3.5 per cent speed regulation (drop in speed from no load to full load) of the prime mover. For each condition the field rheostat should be set for normal rated voltage at the beginning of each test.

Compound-wound generators should be designed as to governing of prime mover, compounding and regulation of the generator, so that with the generator at full-load operating temperature, and starting at 20% load with voltage within 1% of rated voltage, it should give at full load a voltage within 1½% of rated voltage. The average of the ascending and descending voltage regulation curves between 20% load and full load should not vary

more than 3% from rated voltage, except for diesel engine driven generators, in which case it should not vary more than 4%.

The voltage regulation of a three-wire generator should be such that when operating at rated current on the heavier loaded side (i.e., positive or negative lead) with rated voltage between the positive and negative leads and a current of 25% of the generator current rating in the neutral wire, the resulting difference in voltage between the positive and neutral leads and negative and neutral leads should not exceed 2% of the rated voltage between the positive and negative leads.



FIGS. 10 and 11.—Voltage drop characteristics of a compound and shunt-wound generator respectively. The compound generator may be designed to produce an almost constant voltage or even a rise in voltage as the load increases by placing on the field poles a few turns which may be connected in series with either the load or the armature. When the series ampere-turns on the field coils are adjusted so that the terminal voltage of the generator is greater at full load than at no-load the machine is said to be *over-compounded*. When the coils are adjusted to cause the generator to deliver the same terminal voltage at both full and no-load the machine is *flat-compounded*. When the adjustment is such that it causes the generator to deliver less voltage at full-load than at no-load the machine is *under-compounded*. See curves a, b, and c, fig. 10, respectively.

In the foregoing, the speed regulation curve of the prime mover should not vary more than 1% from a straight line drawn between the speeds at 20% load and 100% load.

The voltage regulation and compounding tests should be made at the works of the electrical manufacturer in accordance with his standard testing practice, using an approximately straight line speed regulation from 20% to 100% in amount as specified by the prime mover builder.

Parallel Operation.—Successful parallel operation is attained if the load on any generator does not differ more than plus or minus 15% of its rated kilowatt load from its proportionate

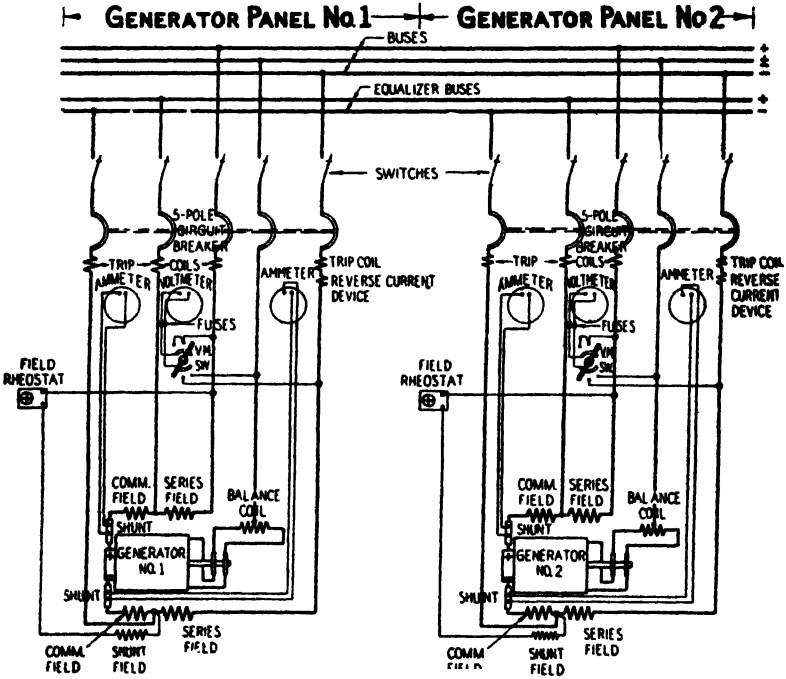


Fig. 12.—Connection diagram of two 120/240 volt three-wire compound-wound d.c. generators. The generators are arranged for parallel operation and require therefore a set of equalizer buses. With reference to diagram each generator has leading from the brushes a commutating and a series field on each leg of the circuit. Between these two fields on each leg is an equalizer connection. Since each generator has a positive, negative and neutral lead, in addition to a positive and a negative equalizer, the total number of outgoing main connectors are five in number. Each of these leads is connected through air circuit breaker and switches to their respective buses usually located in the rear of the generator panels. To prevent motoring of either unit one pole of each circuit breaker is equipped with a reverse current relay, in addition to the over-load trip feature. One voltmeter is provided with each generator, and permits the operator by means of the voltmeter switch to read the voltage between the positive and negative and also voltage positive and negative to neutral. By placing one ammeter in each outgoing leg it is possible to note the amount of unbalance in current at all times by a simple subtraction of readings.

share, based on the generator ratings, of the combined load, for any change in the combined load between 20% and 100% of the sum of the rated loads of all the generators. For this test the speed of the generators shall be constant or slightly decreasing, with the change in speed approximately proportional to the load. For *compound-wound machines*, series field equalizer connections are required, which, between any two machines, shall not have more than 20% of the resistance of the series field with resistors, if any, of the smaller machine.

Prime Movers.—Generating sets may be driven by *steam engines* either of the turbine or reciprocating type, or by *diesel engines*. Each prime mover should be fitted with an efficient speed regulating governor as well as an *automatic overspeed trip*. The automatic overspeed trip should function to shut down the unit automatically when the speed exceeds the designed maximum service speed by more than 15%. Each prime mover should, in addition, be under the control of an efficient *operating governor* capable of limiting the speed, when full load is suddenly removed, to at least 5% less than that of the overspeed trip setting. The overspeed trip should also be equipped with a means for manual tripping. Where a turbine prime mover is also fitted to utilize auxiliary exhaust, it should be provided with a properly arranged automatic shutoff, and where provision is made for extraction of steam, positive means should be provided for preventing a reversal of flow to the turbine.

All sets of 100 *k.w.* capacity and above should be provided with a coupling fitted to the armature shaft.

Mountings.—The generator and its driving unit should be mounted on a *common support* to *insure proper alignment*. Care should be exercised to secure a rigid foundation. Where a bedplate is used, each unit comprising the set should be provided with ample supporting feet secured to the bedplate.

Accessibility.—The design of generating sets should provide for accessibility to all parts requiring inspection during operation or dis-assembling for repairs.

Insulation of Windings.—All assembled armatures and also the armature coils for open slot construction should be immersed in insulating varnish and baked. All field coils should be treated with varnish or other insulating compound while being wound, or impregnated by the vacuum and pressure method The finished winding should be water and oil resistant.

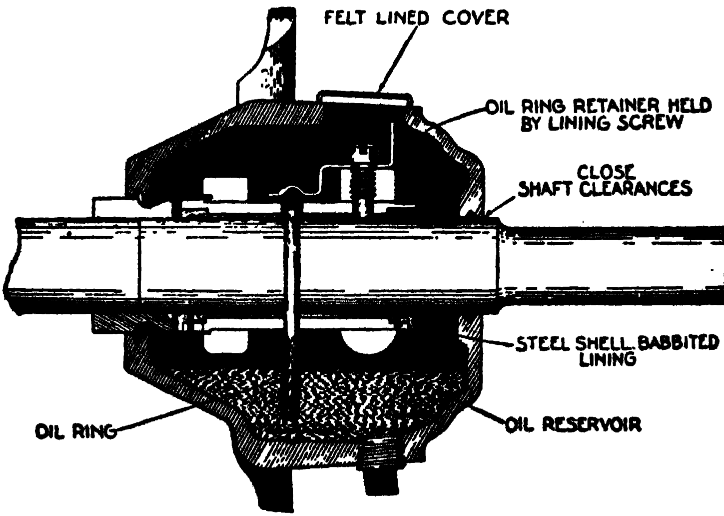


FIG. 13.—Sectional view of a typical self-oiling bearing. As shown the pedestal or bearing standard is cored out to form a reservoir for the oil. The rings are in rolling contact with the shaft, and dip at their lower part into the oil. *In operation*, oil is brought up by the rings which revolve because of the frictional contacts with the shaft. The oil is in this way brought up to the top of the bearing and distributed along the shaft gradually descending by gravity to the reservoir, being thus used over and over. A drain cock is provided in the base so that the oil may be periodically removed from the reservoir and strained to remove the accumulation of foreign matter. This should be frequently done to minimize the wear of the bearing.

Lubrication.—All generating sets should be located with their shafts in a *fore* and *aft direction* on the vessel and they should lubricate and operate satisfactorily when permanently inclined to an angle of 15° athwartship and 5° fore and aft, and arranged so that they will not spill oil under a vessel roll of 30° each side of the vertical. Turbine driven generating sets depend ing on forced lubrication should be arranged to shut down *automatically on loss of oil pressure.*

Corrosion-Resistant Parts.—To prevent deterioration and corrosion of interior bolts, nuts, pins, screws, terminals, brush-holder studs, springs, etc., and such other small parts as would be seriously damaged and rendered ineffective by corrosion, these should be made of corrosion-resistant material or steel suitably protected against corrosion. Steel springs should be treated to resist moisture in such a manner as not to impair their spring quality.

Terminal Arrangements.—

(1) *Generators* 50 *k.w. and above*

(a) *Side location*

Generators should be provided with an insulating terminal board having secured terminals to which the lugs of the incoming cables can be readily fastened. The terminal board should be enclosed in a drip-proof terminal box so constructed that the incoming cables can be led individually through an insulating cover screwed or bolted to the bottom or through a metal strip at least ¼ in. thick. If the cables enter through the bottom, ordinary clearance holes are recommended. If the cables enter through the top, individual terminal tubes should be used.

(b) *Top location*

Generators should be provided with an insulating terminal board as recommended in (a) enclosed in a drip-proof box having top and side sections at least ¼ in. thickness through which the individual cables can be entered through terminal tubes.

(c) *Bottom location*

Generators should be provided with strap terminals, secured to an insulating block, to which the connections (or straps) of the incoming cables can be fastened. The terminal board should be suitably protected.

(2) *Generators below* 50 *k.w.*

Generators should be provided with a side located, drip-proof conduit box with removable cover plate. The generator cables should be secured inside the conduit box. The arrangement should be such as to permit ready connection of the incoming cables.

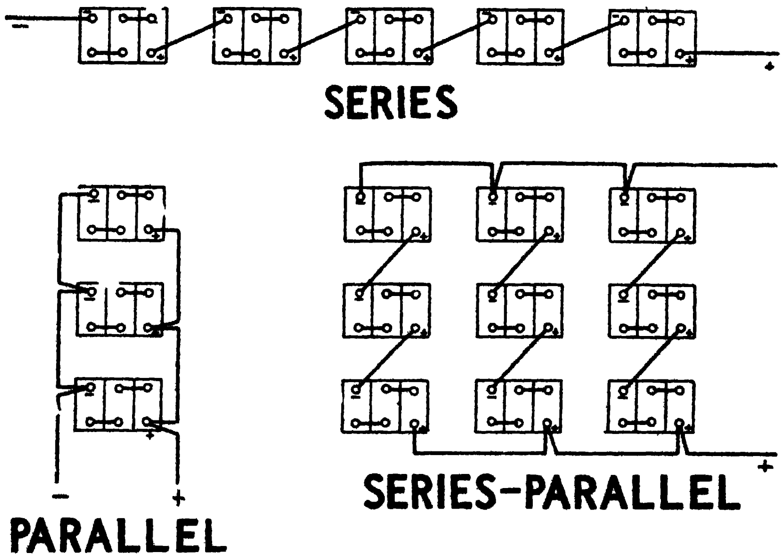
Storage Batteries

Installation and Location.—Storage batteries of either the *lead-acid* or *nickel-alkaline* type should be installed in a well ventilated room, but if no room be available, they may be installed in special deck boxes. The battery room should be large enough to provide adequate access for inspecting, testing and watering the battery.

For a *lead-acid* battery, the exposed metal in the battery room, including the battery and its connections, should be printed with corrosion-resistant paint. The floor of the battery room should be lined with 8 pound sheet lead, carried about 6 inches up the sides of the room and secured thereto or the batteries should be installed in lead-lined shelves with the lead carried up not less than 3 inches at the front, back and end of shelves. All joints in the lead lining should be lead burned watertight. A two inch space should be provided in back of the battery shelves to prevent pocketing of gases.

For a *nickel-alkaline* battery, the exposed metal in the battery room should be painted with corrosion-resistant paint. When the decks are made of ferrous metal, a steel pan should be provided with side walls 6 inches high and made liquid tight. Battery trays can be arranged in tiers, but each tier should be fitted with a pan to take the battery tray.

Where the decks are made of wood or non-ferrous metal, a steel pan of satisfactory thickness with side walls 6 inches high and made liquid tight should be provided. Where the battery rack is located in close proximity to a wooden or non-ferrous bulkhead, the size of the steel pan should be carried up the bulkhead to a point at least 1½ inches above the filler caps of the battery.



FIGS. 14 to 16.—Three principal methods of connecting batteries. For best results it is necessary that all inter-connected batteries be of an equivalent type, that is, their terminal voltage and internal resistance be equal.

The ventilating system for battery rooms should be carefully arranged to prevent the accumulation of pockets of *inflammable gases*. If the battery room be located in a deck house, natural ventilation may be used with adequate openings overhead, and near the deck. If the battery room be below deck, a motor driven exhaust fan, capable of changing the air every two minutes, should be provided for use when charging the battery. The fan should draw from top of room and openings for air inlet should be provided near the base of the room. The interior of the fan and ducts, if used, should be painted with corrosion-resisant paint.

If batteries are installed in engine rooms and machinery spaces, the ventilating systems of these spaces should be of a capacity to properly carry off all gases during the charging period and prevent the accumulation of pockets of *inflammable gases*. When *lead-acid* batteries are installed in special deck boxes, they should be lined with 4 pound sheet lead to a height of 10 inches. Ventilation should be provided by means of an inlet and outlet. The inlet should be turned down and the outlet should extend at least 4 feet above the battery box; both should be suitably protected against spray and painted with corrosion-resistant paint.

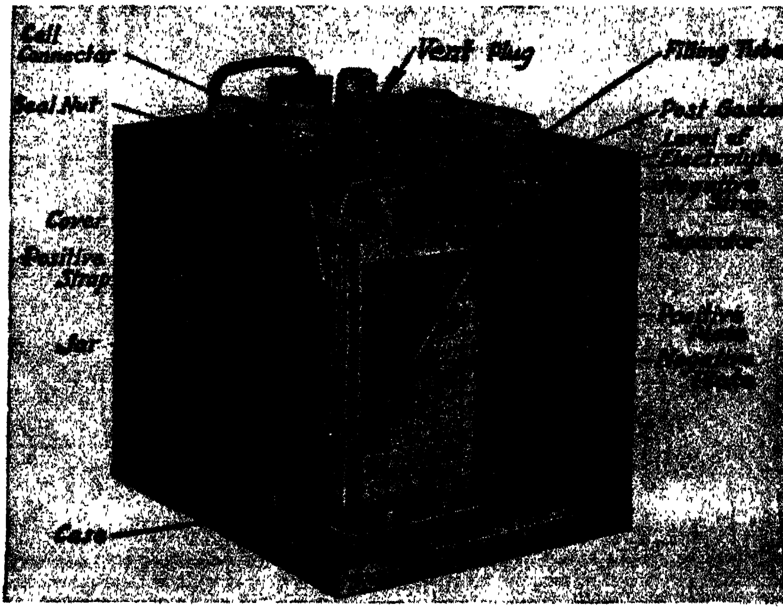


FIG. 17.—Sectional view of Exide battery show[illegible]. The active material is lead peroxide on the *positive* plate and finely divided or sponge lead on the *negative* plate. The plates are immersed in a solution of sulphuric acid and water called electrolyte. On discharge of the battery, both these active materials are quantitatively converted into lead sulphate at the expence of the acid radical of the electrolyte and the formation of water. Precisely the reverse action takes place upon the charge of the battery.

When *nickel-alkaline* batteries are installed in special deck boxes, the box should be lined with sheet steel of satisfactory thickness to a maximum height of 10 inches. The floor of the deck box shall be covered with removable wood strips of at least ½ in. thickness. In addition, the battery shall be

securely blocked in place by means of wooden strips of ¾ in. x 1½ in. cross section permanently attached to the inner sides of the box and placed at least 1½ in. apart in such a way that all trays are held at least ¾ in. from the inner lining. A reasonable amount of ventilation should be provided by locating holes as high as possible on opposite sides or ends. Openings on one side or end are not enough to insure positive ventilation. All wooden lining bases and exposed steel surfaces should be covered with corrosion-resistant paint.

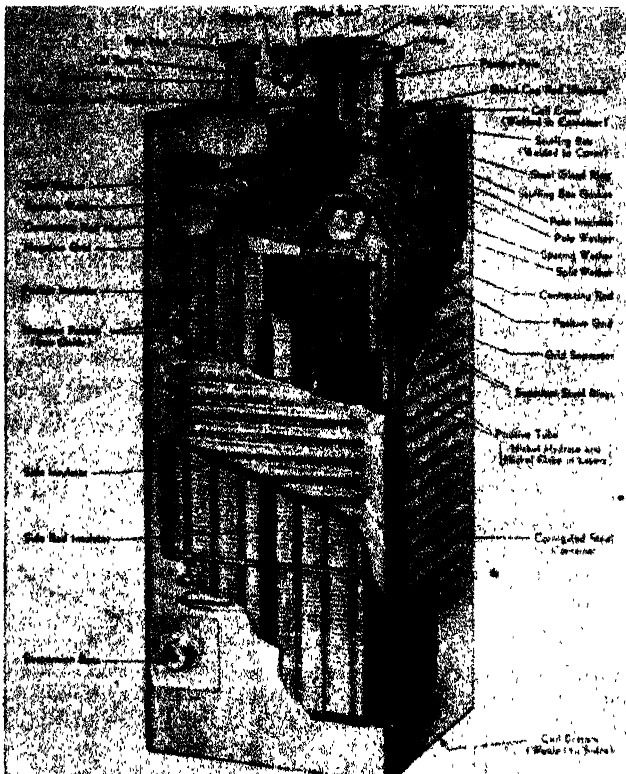


FIG. 18.—Sectional view of Edison Nickel-Iron Alkaline battery. The *positive* or nickel plate consists of a number of perforated steel tubes heavily nickel plated and filled with alternate layers of nickel and hydroxide and pure metallic nickel in thin flakes. The *negative* or iron plate consists of a grid of nickel plated cold rolled steel that holds a number of rectangular pockets filled with powdered iron oxide.

When *radio, emergency radio* and *auto-alarm* batteries of the *lead-acid* type are installed in boxes, the boxes should be lined with 4 pound sheet lead to a height of 3 inches.

When *radio, emergency radio* and *auto-alarm* batteries of the *nickel-alkaline* type are installed in boxes, the interior of the boxes should be fitted with steel pans having a height of 4 inches.

The location of the battery should be carefully considered at the time of installation, and should be such as to protect the battery from damage in case of accident, so far as this is possible. Batteries used for emergency lighting or to operate radio equipment sets, should be located as high as possible, and never below the bulkhead deck level. In selecting the location, exposure to extreme heat or cold, vibration, steam or salt water should be avoided.

Storage batteries of either the *lead-acid* or *nickel-alkaline* type should not be installed in sleeping quarters.

Capacity.—When only a storage battery is required for the operation of the emergency lighting and power system, the capacity of the battery should be sufficient to operate the system for at least 12 hours. For passenger vessels where storage batteries are required for the operation of the emergency lighting and power system in conjunction with the diesel emergency generating set(s), the capacity of the battery should be sufficient to operate the portions of the emergency lighting and power system for at least 1½ hours.

The *capacity* of the *emergency lighting* and *power storage* battery should be such that when connected to the line for the purpose of supplying power, the initial voltage should not exceed the normal rated generator voltage by more than 5% and the final battery voltage at the end of full-rate discharge, should not be more than 12½ per cent below the normal rated generator voltage. The initial capacity of a lead plate type battery should be based on a specific gravity of electrolyte when fully charged between 1.210 and 1.220 at a temperature of 25°C.

The *capacity* of a battery that is normally floated on the power bus, so as to take care of load peaks, should be determined for each particular installation. The *generators* which must operate in parallel with the battery should have voltage characteristics suitable for the type and capacity of the battery, to insure stable operation. Automatic voltage regulators should be

provided to protect the distribution circuits which will not function properly if operated above their designed voltage.

The *capacity* of batteries when provided as the only power supply for *signalling, communication* or *alarm systems*, should be sufficient to operate the equipment connected thereto under normal conditions for at least one week without charge. It is recommended that a standby battery be provided for such systems to permit operation from alternate sets.

It is recognized, however, that in special cases there may be some unimportant equipment where a capacity sufficient to operate the equipment for 72 hours may be adequate, when a spare set is provided and the ampere hour capacity is not less than sixty.

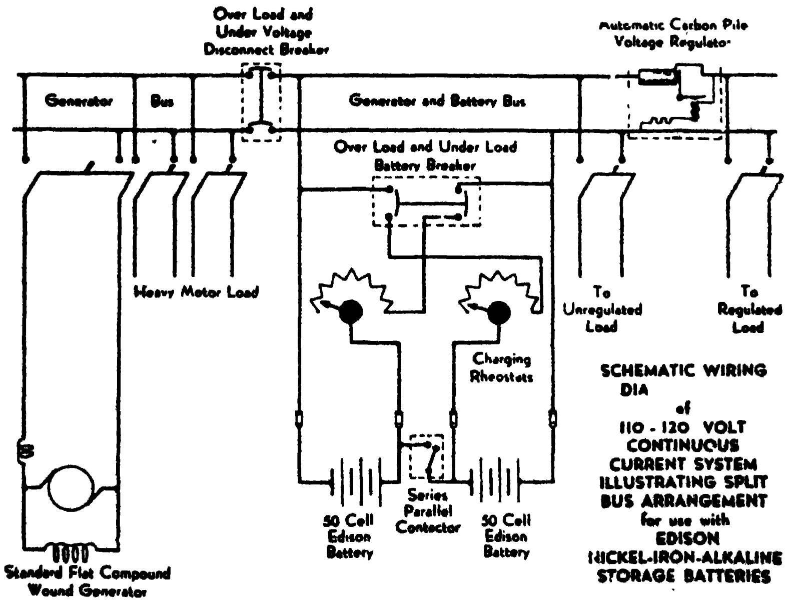


FIG. 19.—110-120 volt battery-generator circuit. An economical arrangement is obtained by means of a disconnect circuit breaker so located in the control circuit that it divides the heavy motor loads from the emergency and lighting loads. This circuit breaker accomplishes two purposes: it relieves the generator of any overload condition and because of the close limits over which the voltage relay operates it provides the emergency and lighting circuits with a continuous source of current through instantaneous transfer of these circuits from generator to battery. This transfer is made upon loss of the generator voltage from overload or any other cause. The generator is then forced to carry the heavy motor loads which are connected ahead of the disconnect circuit breaker.

Batteries for starting *marine diesel engines* and other service, shall have a fully charged specific gravity of not less than 1.275 to 1.285 at 25°C. Batteries shall have sufficient capacity for the necessary breakaway current voltage, and to crank the engine for not less than two minutes at a speed sufficient to insure starting the engine at the lowest temperature anticipated.

Batteries used for starting duty only may be furnished in thin positive plate construction (.100 to .150 thick); however, when auxiliary duties are to be performed from the battery, heavier positive plate construction shall be considered (.150 to .250 thick). *Exception*—Starting batteries which will be continuously exposed to tropical temperatures shall have a fully charged specific gravity of 1.210 to 1.220 at 25°C.

Batteries should develop at least 90% of their rated capacity within the first three cycles after assembly.

Accessibility.—The battery should be arranged so that the trays are readily accessible for care, inspection and removal. Lifting eyes or equipment should be provided over all large batteries to facilitate removal.

Voltage.—The emergency lighting and power batteries should supply a voltage equal to that of the vessel's supply.

Charging Equipment.—Where the voltage of the battery is the same as ship's supply, the battery may be split for the purpose of charging. The capacity of the charging equipment should allow the entire battery to be charged at once. Emergency lighting and power batteries should be charged at their normal charging rate, and time for complete recharge should not exceed 18 hours, based on the 1½ hour discharge rate. The battery and charging equipment should be protected against overload and reversal of current by means of efficient circuit interrupting devices.

The *charging panel* should include an ammeter and voltmeter of suitable range, provided when desired, with switches to read different circuits. A

fixed resistor should be provided for each battery. The charging circuit of the battery should include an overload and underload, or overload and reverse-current circuit breaker. The use of an automatic charging panel is recommended.

Switches and other electrical fittings which are liable to cause an arc are not to be located in the battery room. Each conductor is to be fitted with a protective device which may be located in the battery room if it is enclosed in an explosion-proof casing; otherwise a protective device is to be fitted in each conductor immediately outside the room. Fuses on the *battery charging switchboard*, when in adjoining compartments, will meet this requirement. Fuses may be used for the protection of emergency lighting storage batteries instead of circuit breakers, up to and including 600 ampere rating.

Where conductors enter the battery room, the holes are to be substantially and tightly bushed as required for watertight bulkheads.

All connections within acid battery rooms should be lead covered cables sealed tightly to resist the entrance of electrolyte by spray or creepage.

Switchboards

Installation and Location.—Switchboards should be installed in the same compartment with generating sets, in a dry place away from the vicinity of steam, water and oil pipes. The switchboards should be so located as to be accessible from front, rear and one end. The space in rear of switchboard should be ample to permit maintenance and should, in general, be not less than 18 inches in the clear. Ample clearance should be given for current carrying parts to ground. Asbestos barriers should be installed above the secondary contacts of air circuit breakers if less than 12 inches from ship's structure. If the space in the rear of the switchboard is accessible to unauthorized personnel, the space should be completely enclosed with metal grill provided with either sliding or hinged doors equipped with a lock.

An insulating grating should be provided on the deck in front and rear of switchboard, and grating should extend the entire length and be of sufficient width to provide adequate operating space. A non-conducting horizontal

hand rail should be provided in front of the switchboard. When current carrying parts are located close to the deck, a guard should be provided to prevent accidental contact with live parts. Wood should not be used in the construction or protection of switchboards except for hand rails. For bulk oil carriers and vessels carrying oil having a flash point of less than 150°F., switchboards should not be located in spaces where vapor or gas is liable to accumulate.

Construction

1. **Panels.**—These should be of non-combustible, non-absorbent, insulating material, free from metallic veins, spots, etc., such as impregnated ebony asbestos lumber, or similar material. Impregnated material should be impregnated all the way through and properly buffed and finished a dull black on all surfaces to prevent accumulation of dust and moisture. Each panel should have a bevel on the front edge. The thickness of panels should be not less than one inch and generally not over two inches, depending upon the equipment installed and the size of the panel. Small panels are preferable.

2. **Framework.**—The supporting framework should consist of metal angle, channel or other shapes with a cross member or sill of liberal dimensions under the panels and rigid tie rods to the bulkhead or flexible ties to the deck above to allow for deflection of the deck without injury to the switchboard. A continuous strip of 1/8 in. rubber should be used between all non-metal panels and the vertical supports and a double strip between the bottom of panels and the horizontal member under them. Any other members necessary to make a rigid construction should be provided. Where self-supporting switchboards with complete box framing are used, the rods or braces to the ship structure should not be required.

3. Dead Front Switchboards.—It is recognized that this type of switchboard protects against accident or shock, and the use of such switchboards is desirable in certain installations. Metal panels may be used, providing all current carrying parts are properly insulated.

Equipment for Generator Switchboards.—The following should be supplied for a two-wire system:

Each generator of 25 *k.w.* and above should be protected by an independent arm or trip-free-from-handle circuit breaker with a separate pole for each power cable. These should be arranged to open at a predetermined overload and should be provided with a suitable *overload time-limiting* device. Generators of less than 25 *k.w.* may have fused knife switches or circuit breaker type switches. Compound-wound ordinary type generators arranged for parallel operations should be provided with equalizer switches and circuit breakers having overload and reverse current trip attachments.

An unfused generator switch which will completely disconnect the generator and the circuit breaker from the bus.

An ammeter for each generator.

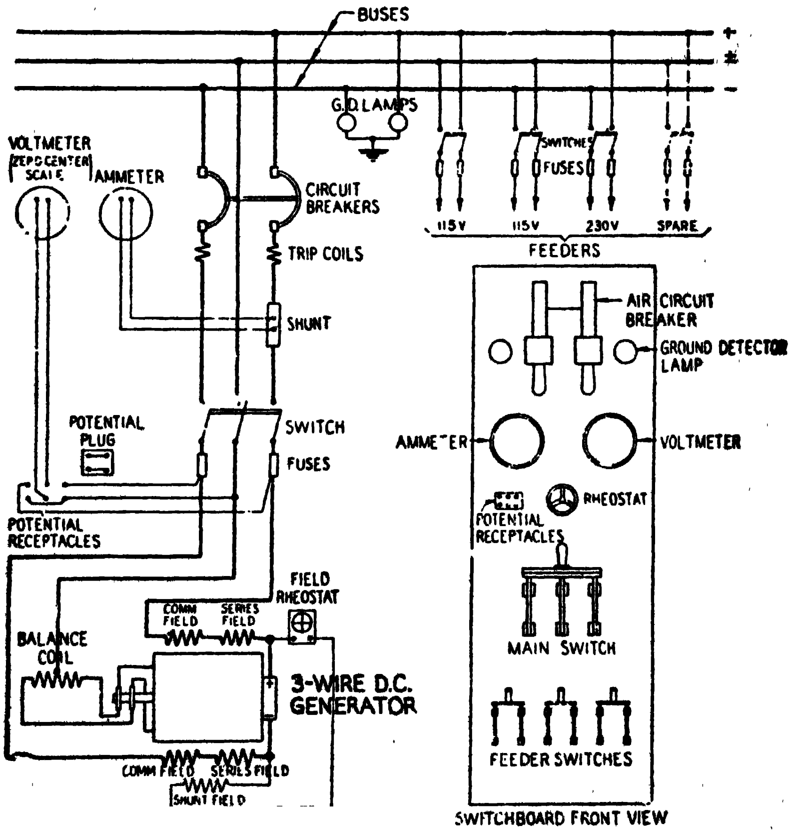
A voltmeter with selector switch for one generator and at least two voltmeters and selector switches for two or more generators.

A field rheostat for each generator.

A pilot lamp for each generator connected permanently between generator and circuit breaker which, in event of the tripping of the circuit breaker, will provide light for restoration of service.

For *ungrounded* systems, ground detector lamps and voltmeter connection or equivalent.

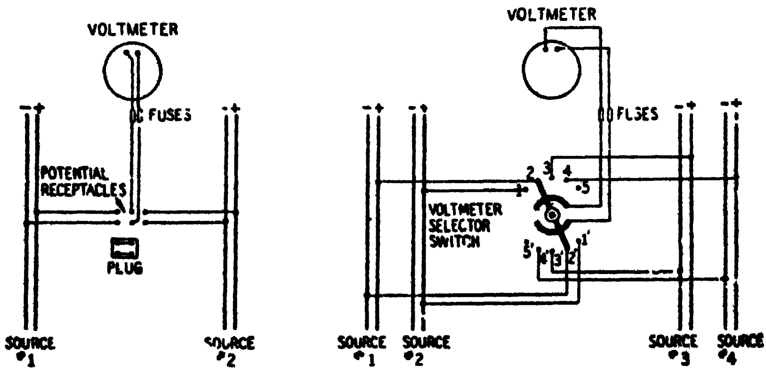
For generators of 500 *k.w.* rating and above, a single-pole field switch with discharge clips and resistor and a watt-hour meter are recommended.



Figs. 20 and 21.—Typical wiring diagram and switchboard arrangement for a three-wire direct current generator. It is customary when using a supply system of this kind for operation of power and light, to connect the motors between the outside wires and the lights equally distributed between the positive and neutral and negative and neutral.

For a *three-wire* system the above recommendations should be followed except: Circuit breaker and disconnecting switches should be arranged in one of the following ways: (The first arrangement is recommended.)

1. A three pole circuit breaker and a five pole disconnect switch with one pole of the circuit breaker and disconnect switch in the neutral lead. The machine side of one breaker pole is connected to the positive armature lead. The other side of this breaker pole is connected through a pole of the disconnect switch to the positive equalizer bus and through half of the series

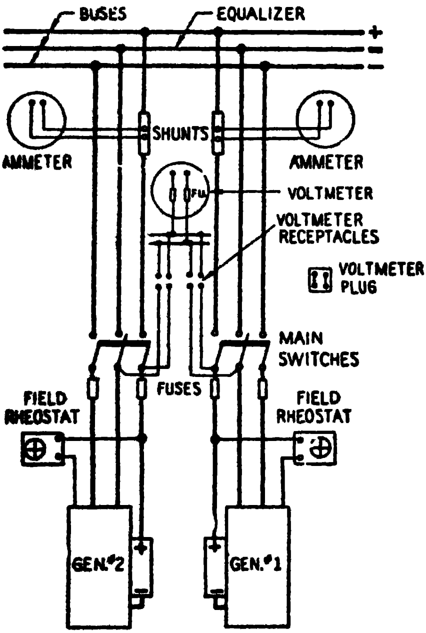


FIGS. 22 and 23.—Methods of measuring voltage from two or more sources or power. In fig. 22 the voltage to be measured is transferred to the meter by the insertion of plug as shown. In the arrangement fig. 23 the voltages across the various sources are measured by means of a selector switch, the operation of which is accomplished by a rotative movement, thus paralleling the meter with the source whose voltage is to be determined.

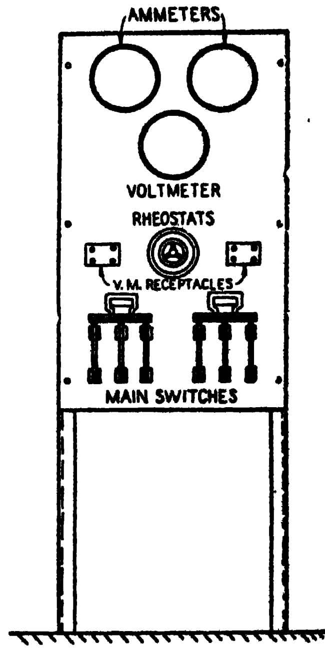
field and a pole of the disconnect switch to the positive bus. The machine side of the other breaker pole is connected to the negative armature lead. The other side of this breaker pole is connected through a pole of the disconnect switch to the negative equalizer and through the other half of the series field and a pole of the disconnect switch to the negative bus. This arrangement requires seven main leads from the generator to the switchboard. *Ammeter shunts* should be located on the switchboards.

2. A five pole algebraic sum circuit breaker with a pole in each armature lead, a pole in each equalizer lead and a pole in the neutral lead; and a five

pole disconnect switch with a pole in each lead. This arrangement requires three main and two equalizer leads from the generator to the switchboard. Ammeter shunts should carry the armature current which requires that they be located at the generator.



COMPOUND GENERATORS



SWITCHBOARD FRONT VIEW

FIGS. 24 and 25.—Typical wiring diagram and switchboard arrangements for parallel operation of two compound generators. When two over-compounded generators are to be operated in parallel, it is necessary for a satisfactory division of loads, to parallel their respective series field. This is accomplished by connecting their negatives together and this common connector is usually referred to as the *equalizer*. The instruments and switches shown are connected in the usual manner, which are similar to those used for connection of shunt generators in parallel, the only addition being the equalizer and connections thereto. It should, however, be noted, that the ammeter for each machine should be connected in the lead from the armature to the main bus, and not in the lead from the series field, because if the ammeter be placed in the latter it will read the series field current which may be quite different from the current supplied by the generator to the load connected to the buses.

3. With either of these two arrangements an overload device may be used instead of a circuit breaker pole in the neutral lead, arranged to trip the circuit breaker. The circuit breaker should protect against a short circuit on the equalizer bus. An ammeter should be provided for positive and negative leads for each generator.

Grounding Three-Wire Dual Voltage Systems.—The neutral connection of three wire 230/115 volt direct current systems should be solidly grounded at the main switchboard with a center zero ammeter in the ground connection. The center zero ammeter should be equipped with a shunt, having a full scale reading of 150% of the neutral current rating of the largest generator and marked "plus" and "minus" to indicate the polarity of grounds.

The emergency lighting and power system is to be arranged so that when operating from a dual voltage emergency generator or storage battery, the neutral will be grounded but the ground connection at the emergency generator or storage battery should not be in parallel with the ground connection at the main generator. The ground connection should not prevent checking the insulation of the emergency generator to ground before the generator is connected to the bus.

Equipment for Distribution Switchboards.—Fuses in excess of 200 ampere rating should not be used for any circuits except for emergency system batteries. Circuits not protected by fuses should have each ungrounded conductor protected by an overload operated circuit breaker or circuit breaker type switch of the independent arm or *trip-free* type. The grounded neutral conductors of a *three-wire* feeder should be provided with a means for disconnecting and arranged so that the grounded conductor cannot be opened without simultaneously opening the ungrounded conductors. *Overload* protection is not necessary in the grounded neutral conductor. Circuit breaker type switches should provide overload and short-circuit protection.

Feeder circuits of 200 amperes or less may be provided with multiple lever type fused switches with one pole for each conductor instead of circuit breakers, except that for three-wire 230/115 volt feeders, no fuse is to be provided in the neutral. All fuses other than instrument fuses should be mounted on the front of the switchboard, except in the case of dead front switchboards. Arc searchlight circuits should be provided with a double-pole independent arm or a *trip-free*-from-handle type circuit breaker and an ammeter.

Two feeders should be provided from the main switchboard to the steering gear room. The overload protection for each steering gear feeder should be an instantaneous circuit breaker set at not less than 300% of the rating of the steering gear motor. The opening of the main switchboard steering gear circuit breaker should operate an audible alarm located adjacent to the principal propulsion control station.

Arrangement of Switchboard Equipment.—When facing front of switchboard, *left hand* contacts should be *negative* and *right hand* contacts *positive*. If, in special cases, it should appear necessary to use horizontal switches, the top contacts should be positive. If the buses are arranged horizontally, the positive bus should be nearest the panels; if arranged vertically, the positive bus should be at the top. Generator circuit breakers should be located at the top of the panels. Below the circuit breakers should be located the meters and if the general switchboard illumination is not sufficient for the scales of these meters other means of illumination should be provided. Below the meters should be located the ground detector and voltmeter switches and the rheostat handwheel, and below these the generator switch should be mounted. For small switchboards there may be room at the bottom of the generator panel for feeder switches.

On the feeder panels where circuit breakers are mounted above each other there should be adequate spacing for the arcing or otherwise protective barriers installed. Switches on feeder panels should be located with the largest ones at the bottom. Sufficient space should be allowed vertically between switches to avoid injury to the hand in operation. No part of any

equipment should project beyond the edge of the panel. Metal framework and instrument cases should be grounded.

Arrangement of distribution boards when separate from the generator boards, should be the same as for generator switchboards as far as practicable.

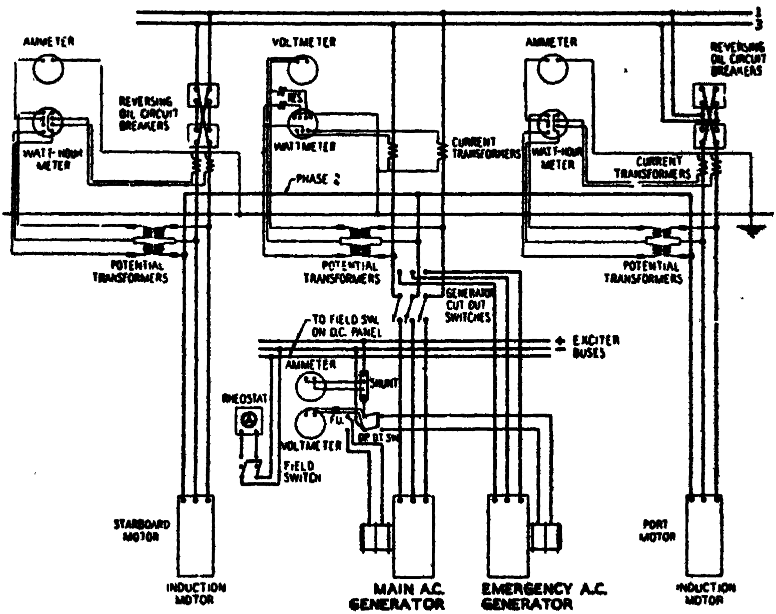


FIG. 26.—Typical wiring diagram of a twin screw turbo-electric propulsion drive with induction motors. The propelling machinery consists of one 5,500 *k.w.* turbo-generator, two induction motors, two water cooled rheostats, one main switchboard and one auxiliary propelling turbo-generator of 450 *k.w.* The machinery is all contained in one engine room. The main turbo-generator is mounted on its bed plate on the center line of the ship. The auxiliary generator is mounted on a platform above the main generator on the port side of the engine room. The two induction motors are connected directly to the two propeller shafts. The ship's 3-35 *k.w.* generators one of which may be used for excitation are located on a platform in the aft end of the engine room on the starboard side. At 15 knots the turbine makes 2,130 *r.p.m.* and the motors run 117 *r.p.m.*, the reduction being approximately 18 to 1. The electrical apparatus except those used for excitation, are of the three phase A.C. type. To reverse the direction of rotation of the propelling motors, it is only necessary to transpose two of the phases. This is easily accomplished by reversing oil circuit breakers operated by means of control levers situated on the control panels.

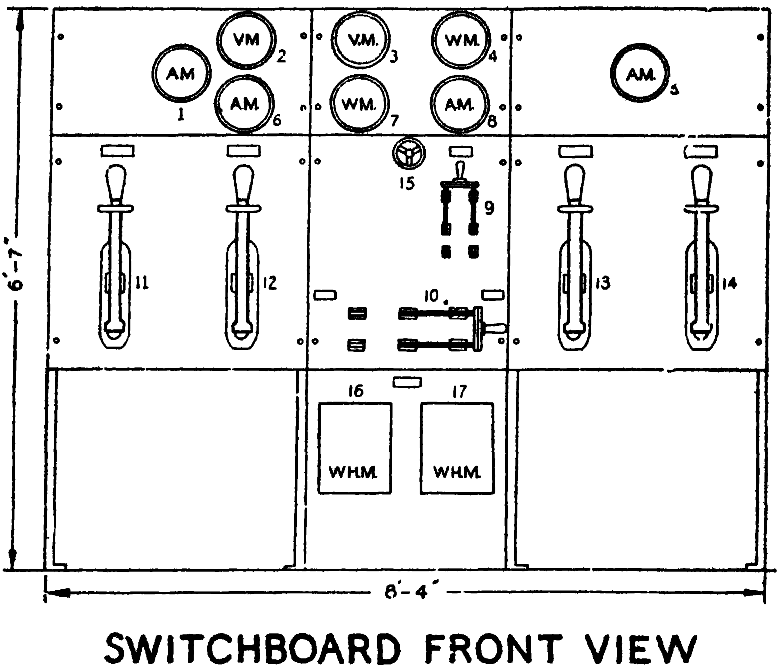


FIG. 27.—Front view of turbo-electric drive switchboard, connected as shown in fig. 26. The instrument and apparatus are: 1, ammeter; 2, volt-meter; 3, volt-meter; 4, watt-meter; 5, ammeter; 6, ammeter; 7, watt-meter; 8, field ammeter; 9, field switch; 10, D.P.-D.T. lever switch; 11 to 14, oil circuit breaker reversing switches; 15, field rheostat; 16 and 17, watt-hour meters.

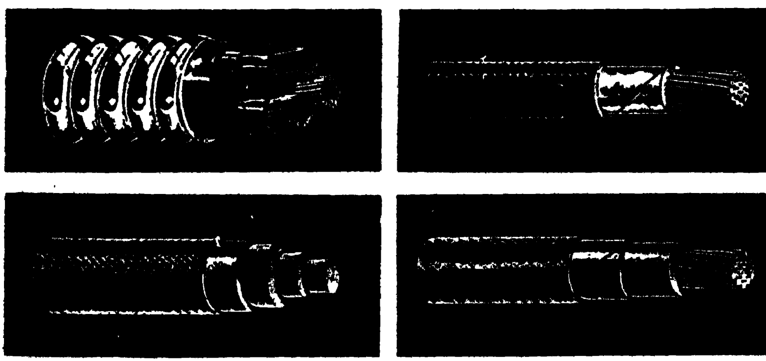
Cables—Applications

Leaded and Armored Varnished Cambric Insulated.—Varnished cambric insulated cable may be used for all cable runs, and should be used for auxiliary power and lighting cables where the ambient temperature is in excess of 50°C. Where varnished

cambric is used, the wire size should not be smaller than No. 12 AWG. (This necessitates the use of No. 12 wire for lighting branch circuits instead of No. 14.)

Leaded and Armored Rubber Insulated.—It is recommended that rubber insulated cable be used in all spaces where the ambient temperature does not exceed 50°C.

Steel, Bronze or Aluminum Armor.—Bronze or aluminum armor should be used for all cables exposed to weather. Steel, bronze or aluminum armor may be used for all other spaces.



Figs. 28 to 31.—Various cables used in electrical installations. Fig. 28 illustrates varnished cambric-insulated cable with interlocked steel armor; fig. 29 glyptal cloth-insulated cable for hot and oily locations; figs. 30 and 31 varnished-cambric-insulated extra flexible apparatus leads and asbestos-varnished-cambric insulated cable respectively.

Armored Cable, Varnished Cambric and Rubber Insulated.—Rubber or varnished cambric insulated armored cables may be used only in quarters for officers and crew and passenger accommodations. Varnished cambric should not be used for wires having cross sectional areas less than No. 12 AWG.

Where lighting fixtures or sockets are not vented or designed to prevent the connecting wires from reaching an excessive temperature, rubber insulated wires should not be used where the conductor temperature will exceed 75°C.

Braided Cable.—Rubber insulated may be used in lighting fixtures except as noted in the previous paragraph. In multiple lamp fixtures 2,580 circular mils stranded, rubber and cotton braid insulated wire may be used for the individual lamps and may be spliced in the lighting fixtures.

Interior Communication Wires and Cables.—For call bell circuits of less than 25 volts, within passenger and crew accommodations, single-conductor bell wire may be used, if properly installed in protected raceways.

For interior communication apparatus, such as *fire alarms*, *telegraphs*, *telemotors*, *signalling circuits*, *control circuits*, etc., requiring two or more wires, interior communication cable should be used and should be either leaded and armored or armored, in accordance with the locations described in the preceding paragraph, except that twin conductor light and power cable may be substituted for twin conductor interior communication cable.

All telephones and telephone systems except those installed for the convenience of passengers and not essential for the operation of the vessel should be wired with either armored, or leaded and armored telephone cable as previously described.

Inter-cabin telephone cable of either the armored or leaded and armored type as described, may be used for the passenger non-essential telephone system.

The American Tel. & Tel. Specification Double-Silk Impregnated Lead Sheath Cable without armor may be used for telephone circuits where a large number of ship's service telephones are installed in passengers' and/or crew's quarters. Bridle wire in accordance with American Tel. & Tel. specifications may also be used for local wiring for ship's service telephones provided it is rigidly held in place, protected from mechanical injury and not exposed to moisture.

Portable Conductors

1. **Rubber-sheathed.**—Conductors for portable cargo fixtures, tools, watertight and non-watertight portables, signalling lights and all portable or semi-portable fixtures outside living quarters should be two-conductor portable rubber-sheathed.

2. **Armored.**—Armored portable conductor cable may be used for the foregoing applications and should be used where the cable is continuously in contact with oil.

3. **Braided.**—Conductors for portable or semi-portable apparatus such as desk lights, flat irons and curling irons used in living quarters may be two-conductor portable braided. However, the parallel conductor rubber-sheathed type portable cable is recommended.

Cable Installation

Cable Continuity and Grounding.—All cables should be continuous between outlet boxes, connection boxes, switchboards, panel boards, switch outlets, receptacle outlets, terminal equipment, etc. For any cable provided with a metallic sheath or armor, the sheath should be continuous from outlet to outlet and should be grounded at each end except that for final subcircuits the sheath may be grounded at the supply end only. Where sheathed or armored cable enters any box or wiring device the sheath should enter the box and should be secured by a clamp or connector to assure good electrical connection between the cable sheath or armor and the box.

Cable Locations.—Feeders of every description should be located with a view to avoiding spaces where excessive heat and

gases may be encountered such as galleys, fire rooms, pump rooms and oil tanks; also spaces where exposed to damage such as cargo spaces and exposed sides of deck houses.

Cables should not be located behind or embedded in structural heat insulation and where they pass through such insulation each should be protected by a continuous pipe, preferably fitted with a watertight stuffing tube at each end.

Generator cables should not be located in bilges unless no other run is practicable.

Cable Protection.—All cables in bunkers and where particularly liable to damage such as locations in way of cargo ports, hatches and tank tops should be specially protected by metal coverings, angle irons or other equivalent means. Horizontal pipes or equivalent used for cable protection should have ¼ in. diameter holes for drainage every five feet.

Cable Support.—Cables where installed in groups should preferably be supported in metal hangers arranged as far as practicable to permit painting all around without undue disturbance of the installation. Cables grouped in a single hanger should preferably be limited to double banking.

Clips or straps used for cable support should each be secured by two screws except that clips for supporting one cable, No. 10 AWG twin or smaller, may be of the one-screw type. Cables supported by clips or straps on under side of beams should be run on backing plates or the equivalent. Cable supports should be spaced not more than 18 in. where vertical and 14 in. where horizontal.

Metal supports should be designed to secure cables without damage to armor or insulation and should be so arranged that the cable will bear for a length of at least ½ in.

Cables—Radius of Bends.—Leaded and armored cables should not be bent to a radius of less than 8 cable diameters. Other cables may be bent to a radius of 6 diameters.

Cables Through Bulkheads, Decks, Beams, Etc.—Where cables pass through watertight decks or bulkheads, a watertight stuffing tube capable of taking packing should be employed. Where cables pass through non-watertight bulkheads, beams, etc., a suitable bushing should be used of such a type as will permit drawing of the cable without damage. When the thickness of the bulkhead or web is ¼ in. or more the bushing may be omitted but the edges of the holes should be rounded.

Cable—Pulling in Force.—No cable should be drawn into wireways where the required pull exceeds twenty times the weight of the cable within the wireway and no appliance should be used which will damage the braid or armor.

Cables.—(Rat Proofing). During the installation of cables due consideration should be given to the feasibility of rat proofing as required by the *Public Health Service.*

Installation of Low Voltage Bell Wiring.—Wires serving low voltage circuits such as call bells for staterooms, public spaces, etc., should be neatly grouped and run together and distributed as required. These wires should be protected by molding, split fibre tubing or equivalent wrapping. The battery and branch leads may be tapped off by splicing. It is recommended that protected accessible connection blocks be used wherever possible instead of splicing within wireway enclosures. Low voltage circuits should be run entirely separate from other systems except when contained in interior communication cable.

Where the public spaces, passages, staterooms, etc., are ceiled, the call bell wiring should be run and secured above or behind the ceiling. Molding may be used in similar locations where there is no ceiling. Call bell wiring leading through crew's quarters and other living spaces where they may be subject to mechanical injury should be protected.

Holes for Cables.—The size of holes required for the installation of the cables for various systems should be such that they will not affect the structural strength of the various members through which they pass.

Distribution—D.C.

Distribution—General.—In general the methods of distribution are as follows: (the number and size of the sub-divisions depending on the size of the vessel and electric plant)—From the distribution section of the main or emergency generator switchboards to:—

1. A branch circuit for an individual controller and motor.

2. A power panel-board then to a branch circuit for an individual controller and motor.

3. A lighting branch circuit.

4. A panel-board then to lighting branch circuit.

5. More than one panel-board, each panel-board serving to subdivide the feeder to a sub-feeder supplying another panel-board or a branch circuit.

6. Another switchboard, then by any individual or combinations of (1) to (5) above, as desired.

Except in the case of small vessels and small electric plants, it is recommended that the lighting distribution system and the power distribution system be maintained as a separate distribution system from the main generator and emergency generator switchboards.

Location and Type of Panel-boards.—All panel-boards should be located so that they are readily accessible at all times to qualified personnel. They should not be located in bunkers,

cargo holds and similar spaces. If the method of operation demands the operation of the switches by unqualified persons, the panel-board should be of the safety type. This type panel-board should be used for the distribution to all lighting branch circuits. Panel-boards located on weather decks or other spaces exposed to the weather or other severe moisture conditions should be watertight, elsewhere they may be of drip-proof construction.

Metallic Circuits.—All circuits should be completely metallic, and no ground return circuits should be employed except for aerial or submarine transmission.

Grounding of Portable Equipment.—Portable equipment such as portable motor units for life-boat hoisting or any other portable equipment fitted with portable cables and attaching devices and which operate on either two or three-wire circuits of 220 volts or more should have their frames grounded.

This should be accomplished by an additional conductor in the portable cable and grounding device in the attachment plug and receptacle.

Demand Factor and Voltage Drop for Generator and Bus.—Conductors from each generator to the generator switchboard should be *calculated for the rating*, including the *two-hour overload rating* (if provided) of each generator.

Conductors between generator switchboards of different generating stations should be *calculated on the basis of* 75% of the station having the *greatest generating capacity*. The drop in voltage from each generator to its adjacent generator switchboard *should not exceed one per cent*.

Conductors from storage batteries to the point of distribution should be calculated for a maximum charge, or discharge rate of the storage batteries, and the drop in voltage from the

storage batteries to the point of distribution ***should not exceed one per cent.***

Conductors from generator switchboard to outlet for receiving shore power should be calculated on the basis of the load required for this condition, or as specified, and the drop in voltage from the outlet to the generator switchboard ***should not exceed two per cent.*** Conductors should be ***continuous*** throughout their length.

Balance of Circuits for Three-Wire Systems.—Since branch lighting circuits are to be of the two-wire type, the three-wire system should not extend beyond the final panel-board. The 115-volt two-wire lighting branch circuits should be so disposed that the load will be ***balanced within*** 15 ***per cent*** at the individual panel-boards as well as for the complete lighting system.

Conductor Identification.—The individual conductors of branch circuit cables should have distinguishing colors, and in grounded systems, the grounded conductor should be connected to the shell of all sockets and all single-pole switches should be in the ungrounded conductor. The ungrounded systems, single-pole switches should be connected to similarly colored conductors.

Feeder Connections.—Where a feeder supplies more than one panel-board, the connection should be of a type that does not sever the conductor, and the connection should be within the panel-board or in a feeder junction box which is readily accessible at all times. In restricted spaces the feeder may be severed at the panel-board provided lugs and special bus bars of sufficient capacity for the entire load are provided which will permit through feed in the event it is desired to disconnect the local panel-board.

Distribution for Navigating Lights.—A separate feeder from the emergency switchboard to the pilot house should be installed for the running, and necessary navigating lights in the *pilot house* and on the *navigating bridge;* any other lights or small apparatus connected to this feeder should be on branch circuits fitted with fuses of no greater capacity than three amperes. Masthead, port, starboard, range and stern lights should be provided with duplicate lamps or a single lamp with two filaments. The duplicate lamps may be connected separately, by means of portable cable to two two-wire receptacles or as in the case of the two-filament lamp, by a single three-conductor portable cable to a three-wire receptacle.

Each receptacle should be connected to an *automatic indicator* located in the pilot house which will give an audible and visual signal on the occurrence of an open circuit. Each individual lamp circuit should be fused and provided with selective switches. The indicator should be enclosed in a steel case unless the magnets are properly shielded.

Distribution for Power Equipment.—In general, power feeders for cargo elevators, cargo hoists and cargo winches which are to be disconnected when the vessel is underway should not be used to supply ventilation sets, drainage pump motors or any apparatus required for the ship's operation.

Separate feeders should be run for engine and fire room auxiliaries, motors for cargo handling gear, steering gear, windlass, radio transmitters, searchlights and ventilation sets. Cargo ventilation fans and fans for ventilation of passenger accommodations should not be supplied from the same feeder.

Two feeders should be provided from the main switchboard to the steering gear room. These feeders should be widely separated so as to minimize failure of both feeders by collision, fire or other casualty. Each feeder should have a continuous current carrying capacity of not less than 125% of the rating of the motor or motors simultaneously operated therefrom.

In order to prevent the spread of fire, recent regulations of the *Bureau of Marine Inspection and Navigation* require arrangements to permit stopping all vent fans from a central point.

Distribution for Heating Equipment.—Separate feeders should be provided for air heaters when extensively used to augment or supplant other forms of heating and the aggregate capacity of the heaters in any one compartment exceeds 5 *k.w.* Isolated heaters, the aggregate of which does not exceed 5 *k.w.* may be taken from other power feeders which are normally energized. An isolated heater, not exceeding 1 *k.w.* may be connected by a separate circuit to a panel-board which is connected to a lighting feeder.

Motor Branch Circuits.—A separate branch circuit should be provided for each fixed motor having a full-load current rating of 6 amperes or more, and the conductors should have a carrying capacity of not less than 125 per cent of the motor full-load current rating. No branch circuit should have conductors less than No. 14 wire.

Heating Appliance Branch Circuits.—Fixed heating appliances having an aggregate rating of not more than 6 *amperes* may be grouped on a branch circuit wired with not less than *No.* 14 *wire* and fused not in excess of 10 *amperes*. Fixed heating appliances having an aggregate rating of not more than 15 *amperes* may be grouped on a branch circuit wired with not less than *No.* 12 *wire* and fused not in excess of 15 *amperes*. Fixed heating appliances having an aggregate rating of not more than 20 *amperes* may be grouped on a branch circuit wired with not less than *No.* 10 *wire* and fused not in excess of 20 *amperes*.

In these cases no other outlets or appliance should be connected to the branch circuit except that current-on indicating lights may be considered a part of the heater. Individual heating appliances with a rating of 15 amperes or more should be wired with a separate branch circuit having a current carrying capacity of not less than the full-load rating of the appliance and protected by a fuse of not greater rating or nearest larger size than

the heater. Indicating lights within the heater may be considered to be protected by the branch circuit fuse. For range units, bake ovens, griddles, broilers, in which self-contained fuses are provided for each individually controlled heating element only one branch circuit need be provided for each assembled unit.

Motors Larger than One-Quarter H.P.—In general, motors larger than ¼ *h.p.* or apparatus consuming more than 660 *watts*, other than incandescent lamps, should not be connected to lighting circuits.

Receptacles for 230 Volt Portable Equipment.—In cases where it is necessary to use 230 volt portable motors the receptacles for their attachment should be permanently marked indicating the voltage and of a type which will not permit attaching 115 volt equipment.

Lighting Branch Circuits.—Connected Load.—It is recommended that in designing the lighting system, the maximum connected load on any branch circuit should not exceed 880 *watts*.

Lighting Branch Circuits—Wire Size.—All branch circuits should be wired with not less than No. 14 AWG conductors.

Lighting Branch Circuits—Over-current Protection.—Each lighting branch circuit should be protected by an over-current device in each wire of no greater capacity than 10 *amperes*, except branch circuits supplying only sockets or receptacles of the Mogul type and wired with not less than *No.* 12 *AWG wire* may be protected by fuses having a rated capacity not greater than 20 *amperes*.

Wire Connections.—Wire joints or connections should be made by screw connections or approved connectors in flame-proof outlet boxes and wiring appliances. Except for portable cords, bell wires and lighting branch circuits the individual wires should terminate in lugs. For lighting branch circuits, wire lugs may be used or the ends of the stranded wire may be formed into eyes and soldered. The lug should be of sufficient size so that it is unnecessary to reduce the wire cross section to permit proper entry into the lug except where the wire size has been increased to reduce voltage drop. Under this latter condition, strands may be removed at the lug entrance but in no case should the remaining cross sectional area be less than that required to carry the maximum current. This exception may not be applicable with some types of mechanical lugs due to the inability to obtain uniform bearing on the conductor.

Use of Outlet and Connection Boxes.—Outlet and connection boxes should be located in accessible locations and not in back of joiner panels unless the covering panels are hinged to permit ready access to the boxes.

Interior Communication Wire and Feeders.—Conductors for interior communication circuits should be calculated for carrying capacities for the rated current of the apparatus connected.

Interior Communication Circuits—Selection of Voltage.—All interior communication circuits should be designed for operation from a 20 volt or a 120 volt direct current or alternating current supply unless the circuits are simple when 12 or 6 volts should be satisfactory.

Interior Communication Circuits—Voltage Drop.—The maximum allowable drop on any circuit shall not exceed 5 per cent of the supply voltage from the point of supply to the most remote outlet under any operating condition.

Interior Communication Circuits—Over-Current Protection.—Where a common feeder is employed for a number of interior communication circuits, each circuit as well as the feeder should be fused and the feeder size based on the connected load.

Interior Communication Circuits—Wire Connections—Except for low voltage call bell circuits, all connections should be made with approved connector or terminal blocks in *flame-proof boxes*. It is suggested that properly protected and accessible terminal blocks be provided for low voltage call bells to facilitate maintenance.

Interior Communication Circuits—Connection Boxes.—Connection boxes where exposed to moisture or used with leaded and armored cable should be of the water-tight type and all others of the drip-proof type; water-tight boxes may be substituted for drip-proof wherever desired.

Special Requirements for Oil Tankers.—For requirements for tankers consult the *Bureau of Marine Inspection and Navigation.*

Conductors and Apparatus in Vicinity of Standard Compass

General.—It is an established fact that generators, motors and conductors carrying currents and particularly grounded circuits have an effect on *magnetic compasses*. The surroundings of the apparatus and wiring, if in steel houses, may reduce to a considerable extent this effect.

For small cables closely associated, carrying small currents, the effect is very slight and for a single lamp for lighting the compasses the conductor, when twisted, may be led inside the binnacle.

The compasses should be adjusted to meet the average operating conditions and the effect of electric circuits in close proximity should be checked by turning them on and off during adjustment.

Direct Current Motors

General.—All motors should be wound for operation on 230 volts direct current (except in the case of installations having a very limited amount of power apparatus where 1/15 volt motors may be used).

Installation and Location.—Motors for mounting on open deck should be of the waterproof type or enclosed in metal housings giving the same protection as a waterproof motor frame. In the case of tank vessels, only enclosed separately ventilated motors should be installed in compartments which may be subject to inflammable gases. All other types of motors should be strictly prohibited in such locations.

Motors should be installed, as far as practicable, with the armature shafts in the fore and aft direction of the vessel. In case motors for service at sea are to be mounted in an *athwartship position*, the manufacturer should be notified.

Accessibility.—All motors should permit ready removal of the armature and field coils and bearings should be arranged to facilitate lubrication and flushing. Eye bolts should be provided for lifting motors of over 150 lb. in weight. All motors except fractional horse power motors should be provided on the commutator end with openings or removable covers of sufficient size and number to give easy access to brush rigging, etc., and permit direct view of the commutator and/or brushes while in operation.

Insulation of Windings.—All assembled armatures and also the armature coils for open slot construction should be immersed in insulating varnish and baked. All field coils should be treated with varnish or other insulating compound while being wound, or impregnated by the vacuum and pressure method. The finished winding should be water and oil resistant.

Lubrication.—Motors should operate successfully for continuous periods when tilted at an angle of 5° fore and aft, and 15° athwartship, and should not spill oil when the vessel rolls 30° either side of the vertical. (In cases where the shaft will be located athwartship, the manufacturer should be advised.)

Terminal Arrangements.—All motors except those of the waterproof type should be provided with drip proof terminal boxes and have the terminal leads suitably secured to the motor frame. The ends of these leads should be fitted with approved connectors. All connections to interior of motors as well as those to the current supply should be provided with efficient locking devices.

The leads of the waterproof motors should be brought out of the motor through waterproof junction boxes. All leads should be located on the *right-hand side* (facing the commutator) unless otherwise ordered. However, both sides of the motor should be so constructed that the waterproof device can be attached in case a change is desired after installation.

Corrosion-Resistant Parts.—All motor interior bolts, nuts, pins, screws, terminals, brush-holder studs, springs, hand-hole cover bolts, nuts and such other small parts, which would be seriously damaged and rendered ineffective by corrosion should be made of corrosion-resistant material or steel suitably protected against corrosion. Steel springs should be treated to resist moisture in such a manner as not to impair their spring quality.

Heating Equipment

Convector and Radiant Type.—Heaters should be suitable for 115 or 230 volts. The sizes recommended are 550, 660, 1000, 1500, 2000, and 3000 watts. The 550, 660, 1000 and 1500 watt sizes may be designed for single heat. The 2000 watt size and above should be designed for at least two heats. The construction of the heaters should be such as to heat the surrounding air by convection. The heaters should be strong, durable and all parts should be of solid construction, capable of withstanding abuse under service conditions. The framework should be metal of substantial proportion and securely fastened together. They should have *non-inflammable* heat insulating material, or adequate air circulation between the heater and surface, upon which it is mounted or to which it is adjacent. When heaters are of the portable type, a suitable clip or bracket should be fitted holding the heater in a fixed position.

Heaters installed on or adjacent to decks or bulkhead should be protected by a perforated or expanded metal covering or equivalent. The ends, back and top may be of solid material. Heaters with exposed surfaces in-

stalled flush with the bulkhead should have such exposed surfaces protected by a screen or guard similar to the other type with the same per cent openings, but the other sides of such heaters should be suitably protected by a solid metal enclosure so designed as to meet the specified temperature limitations. Heaters for mounting on bulkheads should have their top slanted or otherwise designed to prevent hanging towels, etc., on the heater.

The protecting guard should be strong enough to resist being forced against any current carrying part and give full protection from electrical or mechanical injury. The openings should be of small size to prevent the heating elements from being short-circuited or damaged by accident. All metal parts of the heater should be suitably protected against corrosion. The heater element may be of the open or enclosed types and the resistor material should be non-corrodible. If the heating unit is of the enclosed type, the enclosing case or jacket should be permanently corrosion-resistant. If the heating elements are of the open coil type, they should be so designed and supported as to withstand vibrations and prevent short circuit with adjacent elements.

The heating elements should be made up of uniform units easily installed and replaced. The elements should be of a material that will not corrode or oxidize. Alloys containing *zinc* are not recommended for this purpose. No material should be used which is *inflammable*. All connections of the heating elements should be *accessible* and so made that they will not become loose from vibration.

The elements should be wired to a terminal block with connectors and the leads brought out through insulating bushings. All insulated parts should be unaffected by the heat from the heating elements. The external temperature of the enclosing cases of the heaters should not exceed 125°C. except the flush type, in which case the temperature should not exceed 100°C. When the heaters are mounted upon or adjacent to the decks or bulkheads, the construction of the heater should be such that the nearest deck or bulkhead surface will not exceed a temperature of 55°C. For test purposes, an ambient temperature of 25°C. should be used. A suitable regulating switch mounted on an approved insulating base should be provided. Heaters should be equipped with a thermal cut-out of the manual reset type that will prevent overheating of the elements. The heater when hot should withstand 500 volts alternating current, 60 cycles for one minute applied between the frame and current-carrying parts.

Every piece of apparatus should have a name plate attached specifying "*Marine*" *manufacturer's name*, *volts*, *amperes*, *watts* and designating number.

Luminous heaters of a type approved by the *Underwriter's Laboratory* may be installed if desired by the owners.

Glow heaters of the incandescent lamp type in which the element is enclosed in an exhausted glass bulb, are not recommended, but should be constructed to recommendations previously stated, as regards fire risk, guarding, etc., and in addition the lamps should be supported in sockets of ample current carrying capacity, preferably of a spring or flexible type; an additional spring support should be fitted at two-thirds of height of lamps to prevent breakage from vibration.

Electric Heaters (Theory).—Electric heaters used aboard ships are for the purpose of *cooking* or for *heating* of *water* or *space*.

The heating effect received is due to the current flowing through its resistance coil. The resistance units are usually wound for the full line voltage of the supply. They are classified in accordance with the number of watts required to operate them, and also in accordance with the number of ways in which the units may be connected such as, *single heat*, *double heat*, *triple heat*, etc.

Single Heat Type.—In this type the resistance units are connected permanently in *series*, *parallel* or *series-parallel* and are operated by closing a switch, fig. 32.

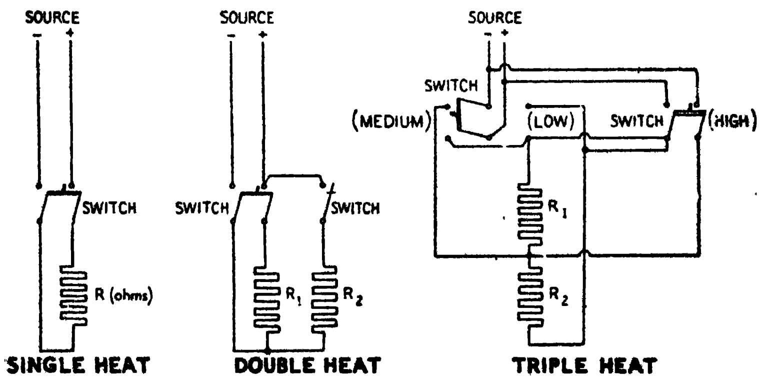
Assuming a potential (E) across the heater coil or coils of (R) ohms resistance, then the heat generated is E^2/R joules per seconds.

Double Heat Type.—In the arrangement fig. 33 the heat is controlled by two switches connecting two equal resistance coils to the source. When closing the double pole switch only resistance R_1 is being heated. The amount of heat generated is E^2/R_1 joules per seconds.

If only the single pole switch be closed the heat generated is E^2/R_2 joules, but since R_1 equals R_2 it is evident that the heating will be the same in both cases. On the other hand if both

switches be closed the heat generated will be $\left(\frac{R_1+R_2}{R_1R_2}\right)E^2$ joules per second or twice the amount generated with only one switch closed at a time.

Triple Heat Type.—With reference to fig. 34 low heat is obtained when the double throw switch is closed toward the right, connecting R_1 and R_2 in series. If E is the supply voltage, the heat generated is E^2/R_1+R_2 joules per second.



FIGS. 32 to 34.—Various heat control circuits.

When the double throw switch is closed toward the left, medium heat is obtained R_1 is connected across the line and R_2 is cut out. The heat generated is now E^2/R_1 joules per second.

Finally when the double pole switch only is closed, R_1 and R_2 are connected in parallel.

The heat is now $\left(\frac{R_1+R_2}{R_1R_2)}\right)$ E^2 joules per second. If R_1 equals R_2 the ratio of the heat obtained is 1/2R : 1/R : 2/R. that is

the medium and high heat are two and four times respectively as high as that of the low heat.

Thermal Units.—The unit of *heat energy is the B.t.u.* (British thermal unit) and is defined as the *amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.* An expression giving the relations between the electrical energy in a circuit and the heat in B.t.u. is:

$$H = 0.057t\,\frac{E^2}{R}$$

Where H = amount of heat in B.t.u.

E = potential of the source in volts

R = resistance of the circuit in ohms

t = time in minutes.

Example.—An electric heater having a resistance of 12.1 ohms is connected to a potential of 110 volts for one hour. How many *B.t.u.* are obtained?

Solution.—A substitution of values in the above formula gives

$$H = 0.057 \times 60 \times \frac{110^2}{12.1} = 57 \times 60 \text{ or } 3{,}420\ B.t.u. \quad Ans.$$

Example.—How much current does a 115 volt 1500 watt heater draw from the line? What should its fuse rating be?

Solution.—The current from Ohm's law is:

$$\text{amperes} = \frac{\text{watts}}{\text{volts}}$$

A substitution of values gives

$$\text{amperes} = \frac{1500}{115} = 13.04$$

The fuses should be the next commercial size above 13, say 15 amperes.

Lighting Equipment

Location of Fixtures.—Lamps should be located preferably overhead, except as a decorative feature in specially equipped rooms. The lamps and wiring appliances should have maximum protection and should not be obscured by moving or stationary objects. When located on bulkheads they should be about six feet above the deck.

Lamps and portable outlets in cargo spaces or on the underside of decks, subject to dropping of heavy weights, should not be fastened to decks, but to clips secured to the side of beams and brackets and should be protected in cargo spaces by metal rods or angles on each side of the fixture or portable outlet.

Attention is directed that some types of high wattage lamps are designed to operate only in either "base up" or "base down" position.

A tell-tale light should be installed outside each refrigerated space to indicate when the lights inside are energized.

Illumination Requirements.—Every compartment, stateroom, office, bath or lavatory should have at least the equivalent of a 25 *watt lamp* or portable for connecting same.

Single lamps or fixtures of more than 50 *watts* should not be used unless diffused by colored or ground glass, except for cargo lighting and for machinery spaces if mounted above range of vision.

Lamps.—All lamps should be selected for the voltage on which they will operate, generally 115 volts. Intermediate base with special shapes and sizes should be used only in spaces as a decorative feature. It is recommended except for instrument lighting that lamp bases not smaller than the intermediate type be used for decorative lighting purposes.

Arc Lamps.—Arc lamps should not be used except for search-lights or moving picture projectors.

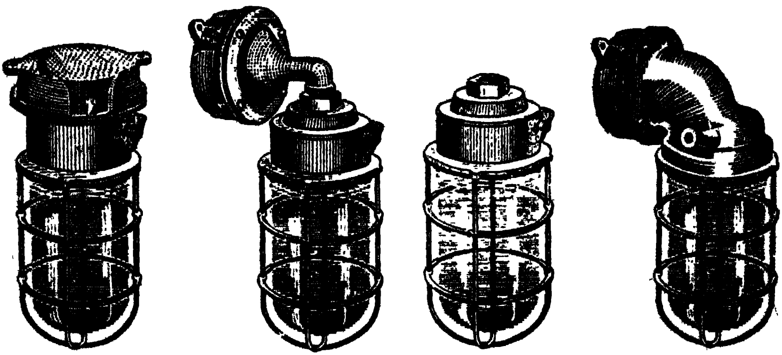
Outlets for Portable Lighting Equipment.—Portable outlets of watertight type should be provided for chain lockers, windlass, deck machinery, steering gear, boiler man-holes, boiler rooms, bunkers, engine room, shaft alleys, refrigerating machinery pump rooms and wherever exposed to moisture.

Non-watertight outlets may be used in baggage rooms, mail rooms, deck lockers, store room, passenger and crew accommodations, deck fan rooms and similar places. All portable lights should be guarded, except when used for semi-decorative ourposes in passenger and crew staterooms. Portable lights should not be used for built-in berths. Lights on beds or other furniture connected by portable cable should have the cable secured to the furniture to reduce the amount of loose cable to a minimum. Cords for bed lamps, floor lamps, table lamps and desk lamps for new installations should in general not exceed five feet in length.

Lighting for Cargo Handling.—Lighting of cargo spaces, hatches and cargo handling gear by large units should only be used when the lighting units are out of range of vision of the persons employed. Outside lighting for lighters, wharves, gangways, decks and hatches should be from overhead. In cargo spaces, lights should be so placed as to protect the light on the cargo ports and hatches.

Permanent Watertight Fixtures.—For outside use, forecastle, poop deck houses and mess spaces (not used as living quarters)

cargo spaces, engine room, fire rooms, steering gear, windlass and pump room fixtures should be made of corrosion-resistant material and should be made watertight. The globe should be protected by a substantial guard.

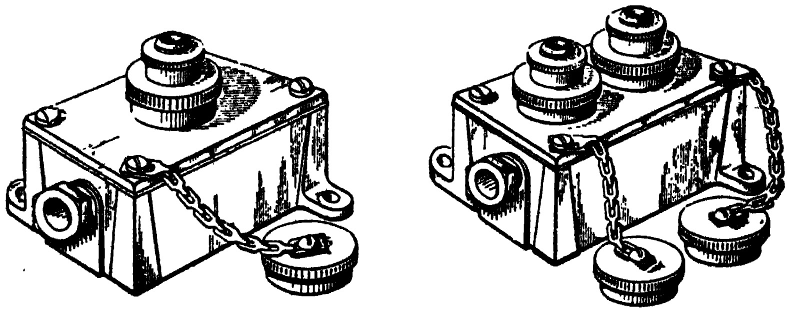


FIGS. 35 to 38.—Represent various types of permanent water-tight fixtures for outside use.

These fixtures should be so proportioned and constructed that when operating continuously with rated size lamp, the temperature will not exceed 35°C. above the surrounding air. Watertight globes should be flanged or of threaded type. Screw threads should conform to the following dimensions:

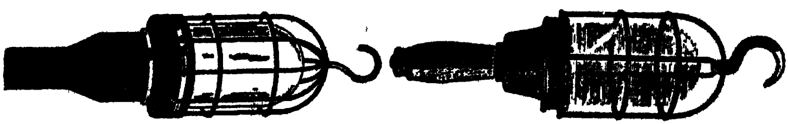
	Inside diameter of globe	Outside diameter across top of thread	Inside diameter across bottom of thread
Globes for 100 watt lamps	$4\frac{13}{32}$ in.	4.859 in. max. 4.844 in. min.	4.734 in. max. 4.719 in. min.
Globes for 50 watt lamps	$2\frac{27}{32}$ in.	3.297 in. max. 3.282 in. min.	3.1719 in. max. 3.1569 in. min.

4 rh threads per inch with a minimum threaded distance of one inch. The radius of the thread should be $\frac{1}{8}$ inch and the center of the first thread should be $\frac{1}{4}$ inch from the edge of globe with threads spaced on $\frac{1}{4}$ inch centers. The inside diameter of globe may have a variation of $\frac{1}{32}$ inch. The base of the fixture should have no less than $2\frac{1}{2}$ threads for the reception of the globe and should be provided with external threads for the reception of the guard.



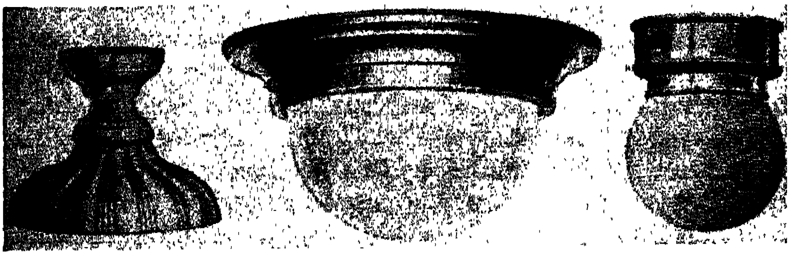
Figs. 39 and 40.—Water-tight receptacle and plugs for one and two outlets respectively.

Portable Watertight Fixtures.—Watertight portables should be similar in construction to the permanent watertight fixtures. The guard should be provided with a hook or ring; also a handle with a stuffing tube for the cable and means to prevent strain on the connections. Portables with bodies of molded insulating material may be used. The use of brass shell sockets is not recommended.



Figs. 41 and 42.—Portable water-tight fixtures.

Portable Non-Watertight Fixtures.—These need not have a globe or stuffing tube, but should be equipped with guard except for semi-decorative desk lights, floor lamps, table lamps, etc., in living quarters and should preferably be composed of insulating material as far as possible. They should be provided with means to prevent strain on the connections.



FIGS. 43 to 45.—Cabin, stateroom and promenade deck fixtures respectively.

Interior Fixtures.—Fixtures for passenger accommodations and living quarters of crews should be substantially constructed and provided with sockets or receptacles which cannot become loose or disassembled through shock or vibration.

Dome fixtures should be ventilated and designed so that none of the adjoining woodwork is directly exposed to the heat of the lamps. Fire resisting material may be provided as a heat insulator. All fixtures should also be adequately vented to prevent excessive temperature from reaching the supply wires.

Emergency Light and Power System

General.—General requirements for this system will be found in *Department of Commerce, Bureau of Marine Inspection and Navigation Rules and Regulations*, and all details of this system are subject to the approval of the *Bureau of Marine Inspection and Navigation*. In general, the following recommendations, though somewhat more detailed, are in accordance with the

Bureau requirements but the latest requirements of the *Bureau* should be used as the authority for each vessel.

Every vessel equipped with an electric lighting plant should be provided with an independent emergency source of power installed above the bulkhead deck, as described in the following sections: *All emergency lights should bear a distinguishing mark for ready identification.* Emergency lights should form a part of the regular lighting system to insure readiness of burning.

Cargo Vessels.—For all vessels of 1600 gross tons and over the emergency source should consist of storage batteries or diesel generating set having sufficient capacity for continuous operation over a period of at least 12 hours when supplying the navigating light circuits, telegraphs, binnacles, and the emergency lighting for machinery spaces, steering gear room, radio room, emergency power stations, passageways, exits from crew's quarters and other spaces and equipment necessary for the operation of the vessel in an emergency. The emergency system should comprise independent circuits from the emergency panel, and be normally energized from the main power source.

Cargo Vessels Less Than 1600 Gross Tons.—Approved safety lanterns may be used for emergency lighting for vessels less than 1600 gross tons.

Passenger Vessels of 1600 Gross Tons or Over.—The emergency source for all vessels of 1600 gross tons and over should consist of one or more diesel engine driven generator sets having sufficient capacity and fuel supply to carry the full emergency load continuously for a period of at least 36 hours, and such final emergency source should be supplemented by a temporary emergency source of power for lighting, consisting of storage batteries having sufficient capacity for continuous operation over a period of at least 1½ hours.

The capacity of the temporary and final emergency sources should be determined by the maximum operating loads of the following groups of circuits. The temporary emergency circuits should provide continuous emergency lighting and power for essential communication circuits during the interval between the failure of main source and starting of the emergency generator.

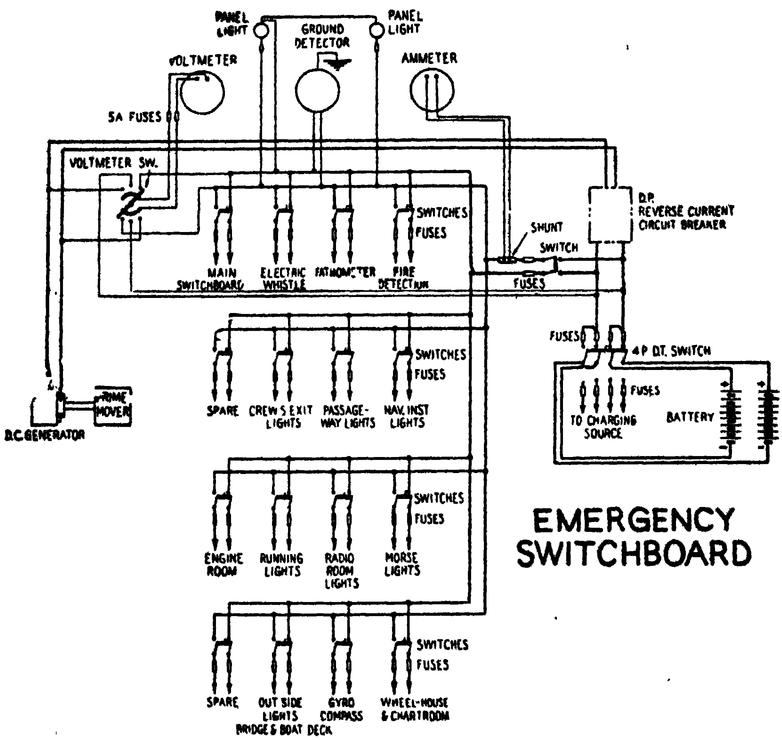


Fig. 46.—Typical emergency control switchboard. This switchboard is usually located on the boat deck and adjacent to the emergency generator set. Power is supplied to the emergency switchboard from the main board on normal operation, and from the diesel driven emergency generator or storage batteries on emergency operation.

The circuits recommended for connection to the temporary emergency lighting storage batteries are as follows:

1. *Temporary Emergency Lighting, Communication and Power Circuits*,

   (a) Navigating lights

   (b) Machinery space lighting

   (c) Radio room lighting

   (d) Passenger and crew exits and passageways (including public spaces) adequately to permit passengers and crew to readily find their way to the boat deck. Lights should be located at least at each end of each section of all fore and aft and athwartship passageways and at each stairway and exit on each deck. In no case should the distance between lights exceed 75 feet.

   (e) At least one light on each berthing compartment accommodating 20 or more persons.

   (f) One or more lights in the galley, pantry, steering gear room, emergency power station, generator space lighting, chart room, pilot house, public spaces, and at all other locations, gauge boards, gauge glasses, etc., essential for emergency operation of the vessel.

   (g) Boat deck lighting.

   (h) Power for essential communication circuits between bridge, engine room, steering station including telegraphs, if electric.

   (i) Watertight door operating gear (if electric) and indicating system.

   (j) General or emergency alarm and fire alarm system.

   (k) Emergency loud speaker system.

2. Final Emergency Lighting, Communication and Power Circuits to be connected to the emergency generator:

   (a) All items enumerated in No. 1.

   (b) Life-boat flood lights. The lighting in the vicinity of the life boats and the boat handling equipment, including the flood lighting of water at the sides of the vessel, should be sufficient to permit the complete operation of loading, lowering and releasing of the life boats.

   (c) Emergency bilge pump, one fire pump, and one sprinkler pump (if provided).

   (d) Other interior communication systems essential for the emergency operation of the vessel.

(e) Radio equipment. (This is in addition to the separate storage battery source required by the Federal Communications Commission.)

The switchboard for the control of the emergency plant should be designed so that all emergency circuits are normally energized through the emergency switchboard from the main generating plant.

The temporary emergency lighting and communication circuits should be transferred to the storage battery automatically upon failure of the main generator supply. In general, all emergency circuits should be provided as independent circuits from the emergency power distribution source. Wire sizes, voltage drops and all other details should conform to the recommendations as previously given.

Passenger Vessels—100 to 1600 Gross Tons.—For passenger vessels of 100 gross tons and less than 1600 gross tons, the emergency source for lighting and power should consist of a diesel engine driven generating set or a storage battery having sufficient capacity to carry the full emergency load for a period of at least 12 hours.

Passenger Vessels—Less than 100 Gross Tons.—For passenger vessels of less than 100 gross tons the emergency lighting system may be approved safety lanterns.

Signal and Communication Systems

General.—Electrical signal systems forming part of the essential operating systems of the vessels should be as independent and self-sustaining as possible. When dependent on a current supply the source of energy should be capable of maintaining the *operation* of the *systems* for a period of *at least twelve hours* and should be independent of the generating plant or as required by the Bureau of Marine Inspection and Navigation.

Electrically operated signalling and indicating systems are recommended for such applications as engine, steering and docking telegraphs and rudder

indicators, in preference to mechanical wire or shaft operated systems where the installation necessitates many turns which may be adversely affected by the varying stresses and strains due to loaded and light condition of the vessel.

Installation and Location of Instruments.—All instruments should be installed with a view to securing the greatest amount of mechanical protection. Lamp type indicating devices should be so located that they do not interfere with the vision of the helmsman for light navigation. Pedestal type instruments should preferably be installed on wood deck blocks and caulked at the deck to prevent water collecting under the pedestal base.

Instruments for bulkhead mounting should be rigidly secured in place and should be mounted at a convenient height for ease in reading. It is recommended that the designation plates and marking for all equipment located on the bridge, essential for the operation of the vessel, be of the luminous type.

Any attachments made to machinery or apparatus for the operation of electrical or mechanical indicators should be such that the derangement of the parts will not interfere with the operation of the machinery or apparatus and the deranged parts can be readily removed.

Instrument Construction.—The construction of the various telegraph instruments should be in accordance with the best standard practice for marine installation, the salient points for consideration being the following:

Instruments should as far as possible, be *water-tight*, fitted with suitable terminal tubes for cable entrance and a connection board with marked terminals for each wire.

The outer case should be of corrosion-resistant material and may be either casting, molding, stamping or fabricated construction. If molded composition be used, it should be flame-proof. All small parts should be of corrosion-resistant material or steel suitably protected against corrosion.

The current carrying parts should be of suitable material for the service, such as brushes, copper connection blocks, etc., and all wearing parts should be of sufficient hardness to prevent excessive wear

All coils should be suitably insulated and impregnated to withstand the conditions of heat, oil or moisture that may be encountered within the instrument by virtue of its own operation or external conditions.

In all electrical instruments (transmitter, indicators, etc.) the transmitting segments, brushes, magnets, motors, etc., should conform to the best general practice as regards construction.

Push Buttons, Bells, Buzzers, Etc.—Construction.—The push buttons, bells and other fittings required in various systems mentioned hereinafter should meet the following general recommendations:

All small parts, including screws, contact elements, etc., should be of *corrosion-resistant material* or steel suitably protected against corrosion.

In all exposed locations, and in boiler rooms, engine rooms, crew's spaces, galleys, working passageways and all similar locations, *water-tight equipment* should be used. The water-tight enclosures for the operating mechanism should be of corrosion-resistant material.

Bells and buzzers should be of rugged construction, suitable for marine service, and not affected by vibration; the appliance to consist of box enclosing the mechanism, cover, and a gong, or vibrator; the mechanism should be readily accessible. The securing of the cover to the box for water-tight appliances should be by means of a coarse screw thread, with a ground joint, or a suitable rubber gasket with four or more securing screws. The box should be provided with at least three lugs for bulkhead mounting, and provide for mounting screws of not less than ¼ in. diameter. Suitable bosses should be provided on the side of the box for tapping for terminal tubes for incoming leads.

There should be at least ¼ inch clearance through air, and ½ inch creepage clearance between all live parts of opposite polarity and between inside of enclosure and any live parts for 115 volts or less.

The exterior surface of the bell box should be painted and gongs should be given a durable finish. The interior of the bell box should be given two coats of suitable insulating paint.

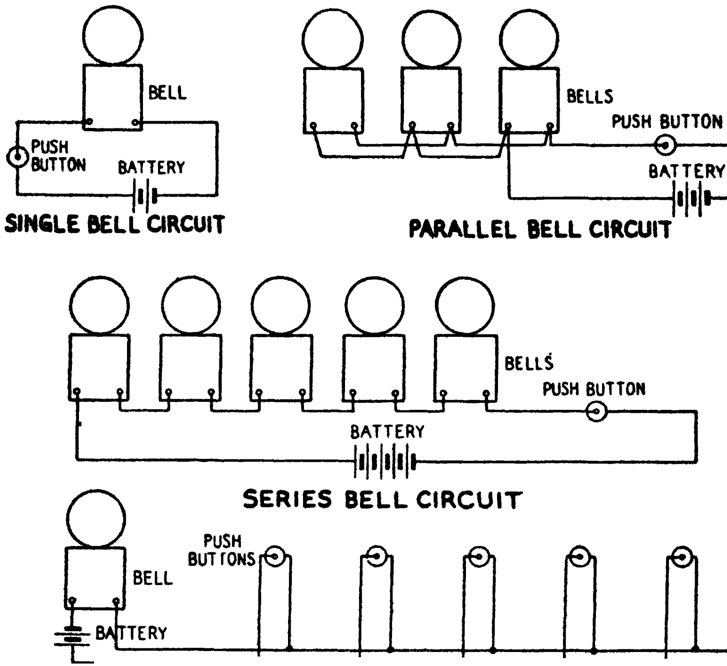
If the design of water-tight bells and buzzers is such that the bell clapper passes through the box, it should be made water-tight. The bell should operate on a 20% reduction in voltage.

Coils should successfully withstand, for a period of 5 seconds, the following high potential test between each electric circuit and ground:

(a) 1500 volts, 60 cylces, for 115 volt coils, or

(b) 200 volts, 60 cycles, for coils of 20 volts or less.

Succeeding the dielectric test the coils should show an insulation resistance of each electric circuit to ground or not less than 1 megohm at 500 volts.



FIGS. 47 to 50.—Various bell circuits. The series arrangement, fig. 49, however, is very seldom used. Since the bells are series connected the potential of the battery must be five times larger than that required by one bell. Another disadvantage is that an open connection anywhere in the circuit will put all bells out of service.

The operation of bells and buzzers should be unaffected by range of temperature from 20°C to 70°C and the winding should be such as to not have a rise in temperature above surrounding air of more than 30°C under 30 minute normal operation.

Name Plates.—All current consuming equipment including telegraphs, bells, buzzers, etc., should be equipped with a suitable *name plate*, giving manufacturer's name, voltage and current consumption or rating.

Engine Order Telegraphs.—Every vessel should be equipped with a *repeat-back signal system* from the navigating officer's station to the engine room.

Any system installed should check within ¼ an indication on the transmitter and receiver and the indication should retain this accuracy. This accuracy should be met with the vessel light and loaded and under the most severe weather conditions. There should be an audible signal with every change in the order and reply.

Mechanically operated telegraph transmitters at the forward and after end of large vessels should not be connected to the same engine room indicator.

Deck mounted transmitters should be mounted with the dials in a fore and aft position, and the movements of the operator's handle should be in the direction of the desired movement of the vessel. The dials should contain at least the following indications or their equivalent:

For Port Dial

Ahead—Full Half Slow

Standby Stop Finished with engines

Astern—Slow Half Full

and should be so constructed that they are plainly visible 10 feet distant and the bridges or deck transmitters should be illuminated from behind the dial for visibility at night. Indicators in the engine room should be mounted as near the operating gear as possible, and equipped with solid brass engraved or the equivalent dials.

Fireroom Order Telegraphs.—Telegraph systems for transmitting orders from engine room to boiler rooms should be of similar construction, installation and operation as engine tele-

graph system; the transmitters need not be illuminated. The markings should be suitable for the system of air, fuel and feed employed or as required.

Docking Order Telegraphs.—Telegraph systems for transmitting docking orders between the navigating positions and the after bridge, should be of the same construction, installation and operation as the engine telegraph systems. *Transmitters* and *indicators* should be *illuminated.*

Steering Order Telegraphs.—Telegraphs for transmitting steering orders should have a transmitter at the bridge, connected to an indicator at the after steering station and steering gear room. The after steering station and steering gear room indicator is to be fitted with a repeat back signal to the bridge, unless a rudder indicator is installed on the bridge.

Rudder Angle Indicator.—On passenger ships and other large ships as required, an electric rudder angle indicator system should be supplied. The transmitter should be located at the rudder head and actuated by the movement of the rudder, the angular movements being indicated in the pilot house. The *angle* of the *rudder* should be *indicated automatically* at the pilot house station and if the indicator does not move synchronously with the rudder but operates step by step, the minimum indications should be bv degrees to ten, then 12½ degrees, 15 degrees and by 5's to 35 degrees. Wherever possible, synchronous type indicating equipment is recommended. The indicator located on the bridge and at the after steering station should be illuminated.

Mechanical Telegraph Installations.—For mechanical telegraph systems all wires, pulleys, chains, sheaves, turnbuckles,

springs and wearing parts should be *corrosion-resistant metal.* Pulleys should be of at least 3¾ in. diameter and provided with suitable holes for oiling. All wire should be of brass, at least No. 10 AWG thoroughly stretched before installation. No splices in wire should be used. Chains in pulleys should be used at all turns; bell cranks should not be used. Wires should be turned and wrapped at gongs and pulls. At chains, they should be turned and provided with sleeves. Where necessary, systems should be provided with springs to take up slack wire in the system.

Mechanical telegraph systems operated by wires should be as direct and have as few turns as possible, and should be so installed as to be accessible at all times.

Wires should not be run behind *insulation* for *refrigerator spaces, through coal bunkers or cargo spaces,* except when *unavoidable* and then should be run through tubes for each wire; the tubes terminating so that wire may be *removed* and *renewed* with the bunkers and cargo spaces filled. Wires should not run *behind paneling of rooms* unless made readily accessible by suitable removable covers. Wire should be supported every three feet or when run through members of the ship's structures should be through holes having a diameter not less than two diameters of the wire and should be so installed that they do not bind on the supports or edge of the holes when in motion.

Wires should be protected by suitable covers throughout their length, except as provided for above and for risers in engine room and between decks, where all wires for a single system, not exceeding four, may be run in one tube and not less than three inch diameter. Wires should be spaced at least ⅝ inch horizontally and ¾ inch minimum vertically between centers throughout system.

Engine Order Bells.—For some groups of vessels, bell pulls instead of telegraphs are permitted by the *Bureau of Marine Inspection and Navigation.* The use of telegraphs is recommended in preference to bell pulls. Bell pull systems employing pulls in pilot house, on bridge and on deck houses operating hammer gongs and jingle bells in engine room should be provided with suitable sounding tube with a receiver embracing

one-half the gong in the engine room connected by at least 1½ in. brass tubing to a flaring transmitter at all the pull stations; the transmission of sound should be such that it can be heard anywhere in the enclosure and five feet distant in open spaces. The material, installation and operation should be the same as described for mechanical telegraphs. The system should be provided with a *label plate* at each mechanical pull, gong and sound transmitter, giving the systems used.

For *Great Lakes* and *River Rules* see *Bureau of Marine Inspection and Navigation Latest Rules.*

Alarms for Cold Storage Spaces.—In order to prevent injury to personnel, all refrigerated spaces and ice boxes for the storage of ship's stores and provisions should be provided with *a mechanical or electrical signal.* A pull or push button should be *located inside* and at the *exit* of each storage space, and the signal

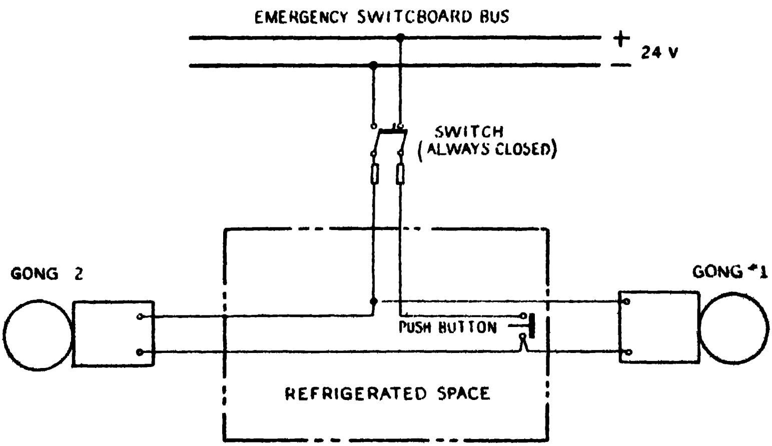


FIG. 51.—Cold storage space alarm wiring. This alarm is designed to protect anyone who may become locked in the cold storage area. The alarm operates from a push button located inside the refrigerated space through gongs or howler located in ship's passageway adjacent to the refrigerated area

should be located within hearing distance of a location where a person is regularly employed. The signal and pull or push button should be provided with a suitable nameplate to designate its function.

Anchor Windlass Signal.—When the operator of the anchor windlass is out of sight of the man handling the chain, there should be installed between the two positions a bell pull system with a pull on deck and a six-inch gong at the operator's position, or in lieu of this, a 1½ in. voice tube.

General Alarm—(Passenger Ships).—A general alarm system is required by the regulation of the *Bureau of Marine Inspection and Navigation*. General alarm system should be provided on all vessels over 100 gross tons and should consist of not less than *eight inch diameter bells* producing signals of a distinctive type from other bells in the vicinity, and so located that their operation will be heard by all *passengers and crew*. These bells should be controlled by manually operated contact makers from the pilot house, fire control station or stations as determined by *Bureau of Marine Inspection and Navigation*. Each bell should be independently fused and the fuses located above the bulkhead deck. *The system should operate from a source of energy capable of supplying the system for a period of at least eight hours and independent of the main generating plant or as required by the Bureau of Marine Inspection and Navigation.*

Day Passenger Ships.—Same as previous except the bells should be so located that their operation will warn all the crew and the passengers occupying staterooms. *In public spaces and open decks alarm to crew should be visual instead of by bell.* The general alarm system is to comply with the *latest Rules of the Bureau of Marine Inspection and Navigation.*

TEST QUESTIONS

1. *The regulations for electrical installation on merchant vessels are promulgated by what government agencies?*
2. *What type of current is used aboard merchant vessels?*
3. *Name the various standard voltages employed on merchant vessels.*
4. *What type of prime movers are usually employed on merchant vessels?*
5. *What are the rules governing installation and location of storage batteries aboard ships?*
6. *Why are storage batteries required for use aboard ships?*
7. *Describe the method used for charging of batteries aboard merchant vessels.*
8. *What are the specifications for installation of switchboards aboard merchant vessels?*
9. *Draw a wiring diagram illustrating method of measuring voltage between several sources of power using one voltmeter and multiple switch.*
10. *By what means are the reversal of propeller rotation obtained on ships equipped with turbo-electric propulsion drive?*
11. *How are current carrying cables supported on merchant vessels?*
12. *What is the maximum permissible voltage drop on interior communication circuits aboard merchant vessels?*

CHAPTER 112

Wiring Under Floors

The problem of arranging wiring under floors with a multiplicity of floor outlets spaced so that they will meet the probable requirements of modern commercial buildings in capacity, flexibility and convenience has led to the development of under floor wiring systems.

In these systems two forms of conduit* are used:

1. Duct or rectangular conduit;
2. Regular pipe conduit.

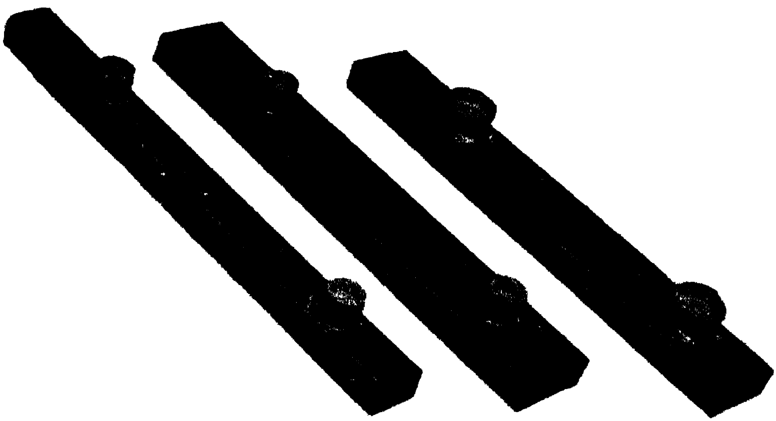
A typical under floor system consists of a network of rectangular steel ducts, single or multiple, embedded in the floor.

Each length of duct is equipped with outlet extensions applied in the course of manufacture, at minimum cost, at specified regular uniform intervals. The advantage of under floor ducts in office buildings is obvious. The practical advantage, economy and convenience of these pre-set, regularly spaced inserts should be just as apparent. Confusion, dirt and noise are practically eliminated in making connections after completion of the building. Flexibility in use is inherent in the principle of under floor distribution and is made fully available by the pre-set insert feature.

*NOTE.—Called *under floor raceways* by the Code.

Figs. 5,671 to 5,673 show the proportions of the duct and the outlets. These ducts come in 10 ft. lengths and the outlets are usually spaced 2 ft. apart.

The sectional view, fig. 5,674, shows one of these outlets with wires passing through it. The outlet as seen has a screw thread. Of course all these outlets will not be used and accordingly plugs are provided to close those not in use. Figs. 5,675 to 5,678 show plug in duct, parts and wrench.

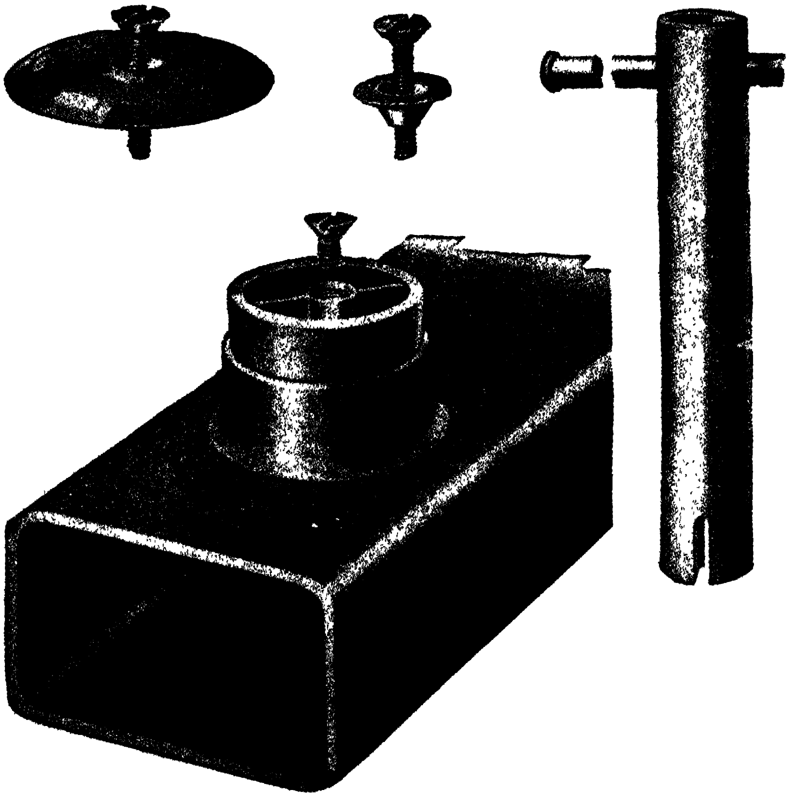


Figs. 5,671 to 5,673.—Walker under floor duct showing outlets. ***Standard sizes*** **No. 1, 1⅛×1¼"; No. 2, 3⅛×1¼'.**

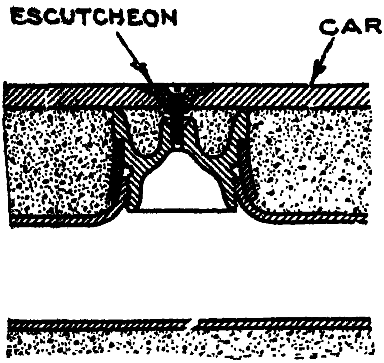
Fig. 5,674.—Sectional view of National duct showing threaded outlet. The sweeping curve is to facilitate pulling the wires.

Fig. 5,683 shows one type of plug.

As shown, the duct is embedded in concrete fill with plugs screwed down into the duct outlets. Plugs may or may not be concealed by floor construction, and marker screw can be elevated to show at floor when required. The construction of the plug is plainly shown in the illustration. The position of the plug is indicated on the floor by the marker screw as shown in fig. 5,679.



FIGS. 5,675 to 5,678.—National duct with plug in outlet, wrench, and parts. Fig. 5,675 shows abandoned outlet plate and fig. 5,676, floor covering escutcheon, fig. 5 678 shows the wrench.



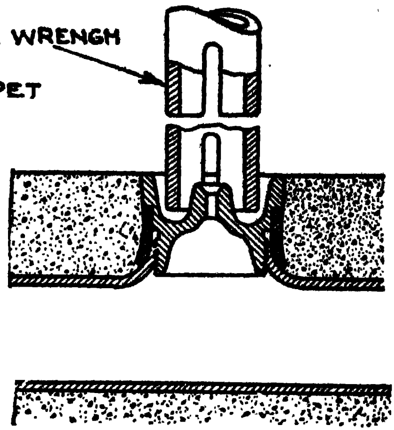
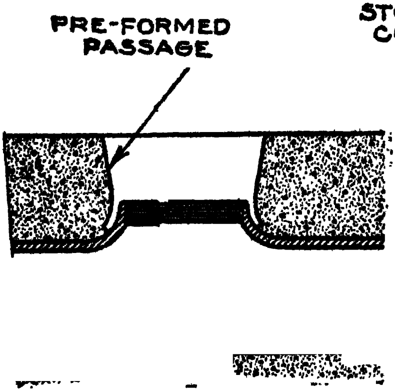


FIG. 5,679.—National type A plug showing application of floor covering escutcheon. When marker screw is to show through floor coverings of linoleum, rubber, cork tile, or carpet, the escutcheon as here shown is used to protect such floor coverings from fraying.

FIG. 5,680.—National type A plug showing application of plug remover wrench.



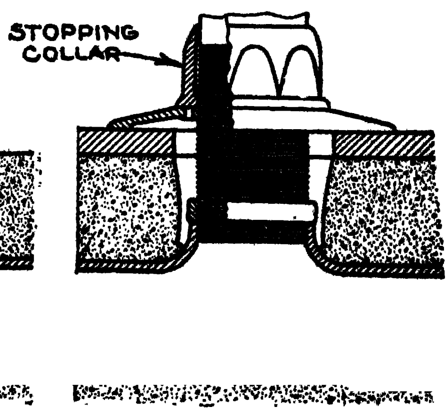


FIG. 5,681.—National duct embedded in concrete showing pre-formed passage through the concrete formed by plug when concrete was poured.

FIG. 5,682.—National service extension assembly showing stopping collar and attachment to duct.

When duct outlet is to be used for service, it is necessary to remove small amount of concrete from top depression of plug in order to use the plug removal wrench.

Plug can be readily screwed from the duct and concrete with plug removal wrench of which the socket end is shown in fig. 5,680. The removal of the plug leaves a neat pre-formed passage through the concrete to duct outlet. The void in concrete around rim of duct is a catch-all for dirt and small particles. Fig. 5,681 shows the outlet with plug removed. The service extension assembly as shown in fig. 5,682, directly engages the duct outlet without use of any form of adapter, insuring positive protective grounding, as required in National Electrical Code. The stopping collar is sweated in place in manufacture, and serves as a gauge so that service extension pipe will always be turned into duct outlet to proper depth.

Fig. 5,683 shows an abandoned outlet.

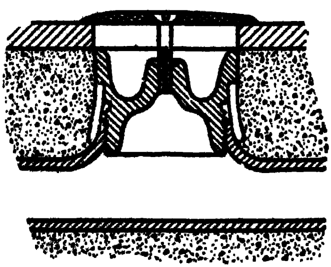


Fig. 5,683.—National type A plug showing abandoned outlet plate.

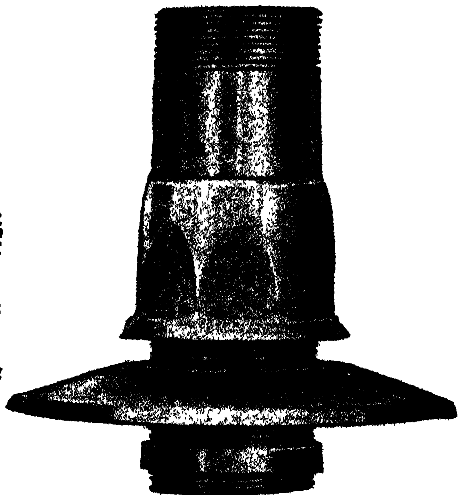
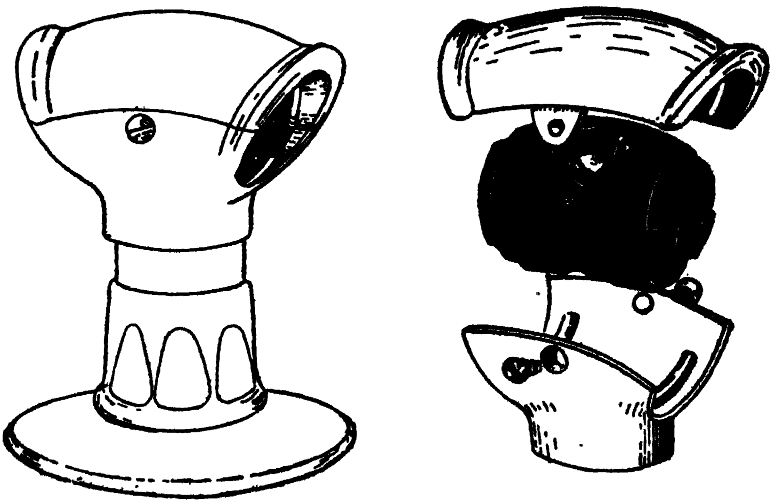


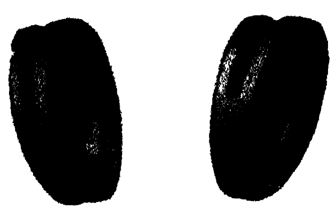
Fig. 5,684.—National service extension assembly. It is adjustable to accommodate floor thicknesses approximately 1 to 2 ins. above the duct. The stopping collar is sweated in place to insure proper depth engagement with duct outlet. When service pipe is screwed into outlet to shoulder engagement, a very tight joint is effected. The floor flange is screwed down to a bearing on finished floor surface, further stabilizing extension assembly. It is provided with holes for spanner wrench, so that by use of the wrench considerable pressure can be applied between floor flange and finished floor, giving extra strength to whole installation. Locking collar is jammed against floor flange by turning it down with other end of spanner wrench. Besides acting as a locknut for floor flange, it hides spanner wrench holes and the unused threads on service extension pipe.

When outlet is abandoned, the plug is screwed again into duct outlet, and an abandoned outlet plate is pulled tight over opening in floor material, by tightening marker screw into plug. The assembly is shown more in detail in fig. 5,683.

Duct Fittings.—Since the service extension assembly and service fittings frequently occupy positions under desks or in foot space, they are purposely designed to be ***kick proof***.



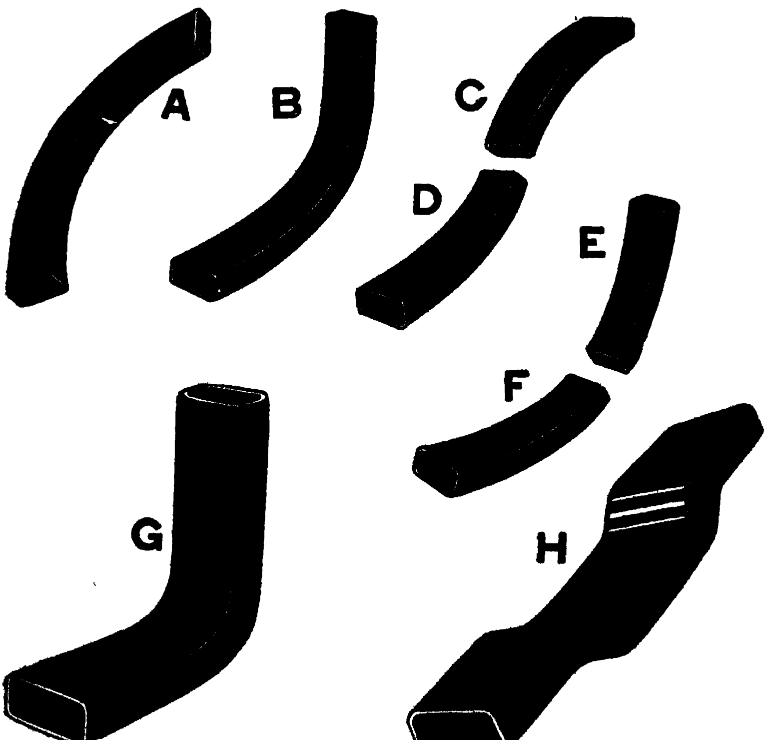
FIGS. 5,685 and 5,686.—National service head shown assembled and disassembled. It is used either for high or low voltage from duct. The double T slot receptacle shown in fig. 5,686 is for high voltage service.



FIGS. 5,687 and 5,688.—National fibre bushings for service fitting used in place of double T slot receptacle for low voltage service. It prevents contact and abrasion between edges of head outlet and wires.

They will stand any reasonable abuse in connection with exposed position. Ribs at two ends of opening prevent desk occupant's feet injuring connection. Attachment plug is sufficiently protected so that the feet will not strike the plug itself, thereby eliminating interruptions to service.

There are numerous patterns of elbows and offsets as shown in figs. 5,689 to 5,696 making it easy to change the direction of the duct in laying.



FIGS. 5,689 to 5,696.—National duct elbows and offsets. Fig. A, flat floor elbow; fig. B, long pattern 90° vertical wall elbow; can be sawed in sections as in figs. C to F, to meet requirements; fig. G, short radius 90° vertical wall elbow; fig. H, cross under offset.

When an outlet is to be connected at the end of duct a fitting such as shown in fig. 5,700 is used. Numerous miscellaneous fittings are shown in figs. 5,701 to 5,706.

Floor Junction Box.—The complete unit comprises the box proper and outlet assembly. The latter is shown in fig. 5,698.

The assembly is installed flush with surface of finished concrete or wood floors. When floor coverings are used, however, the brass ring is forced up, using novel arrangement of screws. Floor covering is then cut to fit around brass ring, and it is replaced in position and drawn down flush with newly installed floor covering. Rim of brass ring holds floor covering down securely,

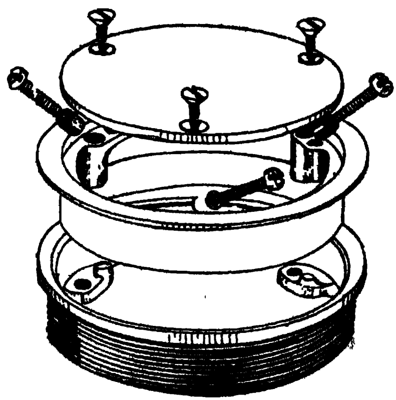


FIG. 5,697.—National standard junction box outlet assembly, for use with finished surface concrete floors, or where floor coverings of linoleum, rubber tile, cork tile, or carpet are laid. The assembly is installed flush with surface of finished concrete or wood floors. When floor coverings are used, however, the brass ring is forced up, using novel arrangement of screws. Floor covering is then cut to fit around brass ring, and it is replaced in position and drawn down flush with newly installed floor covering. Rim of brass ring holds floor covering down securely, and renders the box waterproof.

and renders the box waterproof. An entire unit consisting of a double box and outlet assemblies is shown in fig. 5,698. It is levelled by adjusting the three long set screws, located around edge upon which the box rests.

Under Floor Duct Layout.—Floor plans, conditions and service requirements are apt to vary so widely that but one general

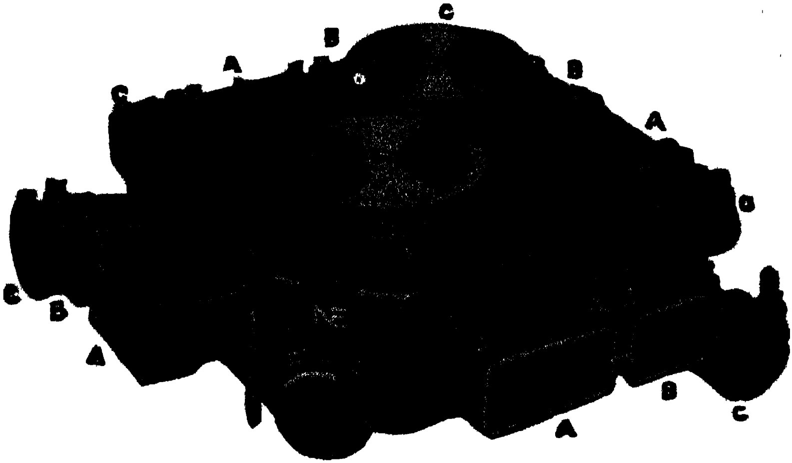


FIG. 5,698.—National 4 way floor junction box. *It is in reality* two boxes and two sets of cross overs, in a one piece casting, one box and cross over to be used for high voltage and the other box and cross over to be used for low voltage. No communication is to be had between the high and low voltage boxes (in accordance with rules of the Code). All openings A, receive large duct intended for low voltage wiring. Openings B, receive small duct intended for high voltage wiring. Conduit openings C, receive conduit, nominally 1¼ inch for high and low voltage service to system. The two outlet assemblies installed in the box are shown in detail in fig. 5,697. Unused duct openings in box should be closed with duct opening plug shown in fig. 5,699, and unused openings for conduit should be closed with conduit opening plug and adapter.

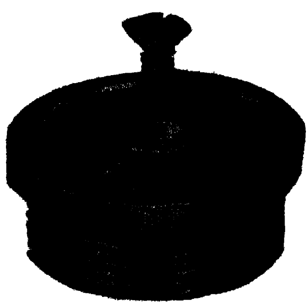


FIG. 5,699.—National type B plug. When adjusted it protrudes very slightly above top rim of duct outlet. This shallow plug is intended for use where duct is installed under wood or marble, as it is impracticable to cut a number of holes in the underside or through these materials to fit over a type A plug protruding above level of concrete fill; when the type B plug is used, holes need be cut only where duct outlet is to be used for service. Other outlets are located by marker screws, or by measurement.

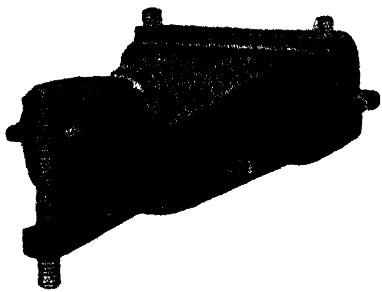
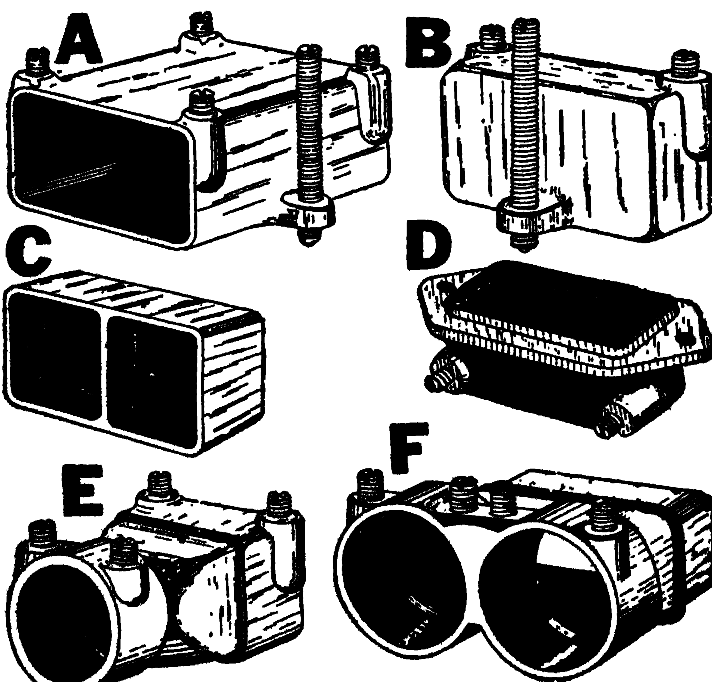
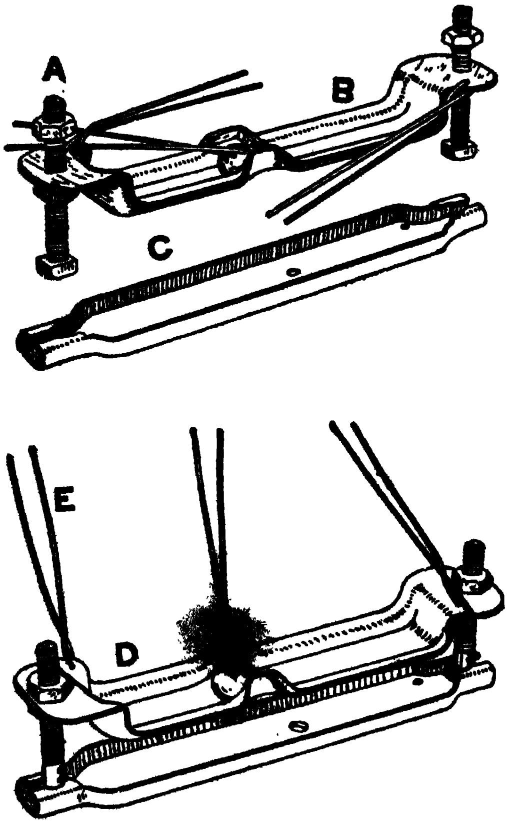


FIG. 5,700.—National duct end outlet with height adjusting screw. It fits on end of the duc, and receives standard duct outlet plug.



FIGS. 5,701 to 5,706.—Miscellaneous National duct fittings.

rule can be laid down to govern all jobs in the matter of layout. That is, the layout need not necessarily take care of all possible conditions, but may provide only for all reasonable probabilities, leaving improbable possibilities to be taken care of if they materialize.



Example. — An 18-foot bay would seem to require for 100% coverage three runs of duct with 4 ft. 6 in. spacing, but two runs, five feet from the wall and five feet from the columns, will usually be sufficient to meet actual requirements. The reason for this becomes apparent when it is considered that a single row of desks would almost surely be placed near the wall, a second row in corresponding position near the columns and a third row, if needed, would have to be doubled with one of the other rows, the double row using a single run of duct. Similarly a 30-foot space would seem to require five runs of duct whereas three runs will cover the probable service demands.

Figs. 5,707 to 5,709.—National duct saddle support, disassembled and assembled. A, height adjustment nuts; B, saddle slips into place when adjusting nuts are loose; C, base members of saddle support are installed on floor as early as possible, to indicate lines of duct, thus avoiding interference of other trades' work; D, seats in saddle for duct are stamped accurately, and hold ducts in proper relation to each other, as well as to the finished floor; E, tie wires to be twisted over top of ducts to hold them firmly in saddle.

Aside from the factor just mentioned, layouts will generally come under one of four classifications, governed by policy and specific conditions.

1. General coverage of entire, net, usable floor area.
2. Full coverage of certain parts of floor area where demands for service will be greatest.

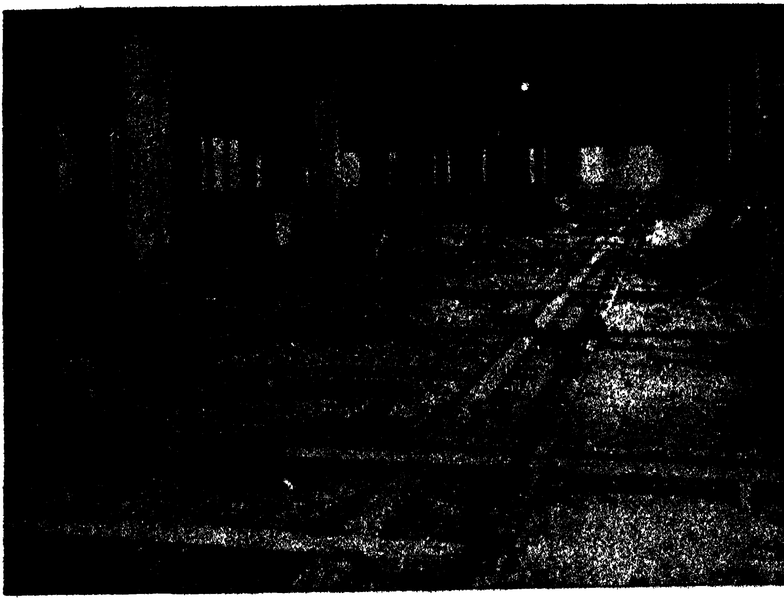


FIG. 5,710.—Example of the use of under floor duct for service around the outside walls of a building where demand for telephone and signal service at least, is apt to be heaviest. This plan gives only a minimum of coverage but does give flexibility. A further point of interest is the use of double size duct for low tension wires—an example of the adaptability of the system to varying service requirements.

3. Under floor duct around the outer wall when service demands are concentrated there. This plan is in general adequate only where space is definitely planned in small units but is extremely flexible and economical for such areas.

4. This class includes all special plans such as those for stores or banking floors where the layout definitely follows the equipment plan.

Another important factor is the number and location of home run or feeder conduits or ducts.

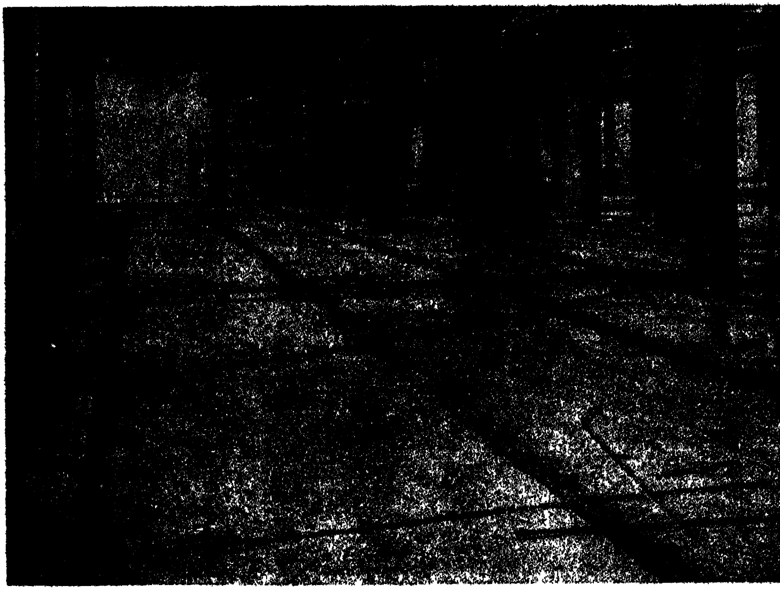


FIG. 5,711.—Walker duct under floor installation so designed as to adequately cover all usable areas making provision for any and all requirements for the life of the building. Double size ducts are used at important feeder points of the telephone and signal duct system. Each sub-panel is fed by a separate riser; cross run feeds are alternately for light current and low tension.

In planning a round conduit system the rated capacity of a conduit may be utilized and in the case of a lighting current system the full capacity of each circuit available may be used.

In the case of under floor ducts, however, every outlet utilized should be a separate circuit as far as the nearest junction box. Therefore, junction boxes and home runs should be spaced. as a rule, not more than thirty or

forty feet apart. If these home runs feed more than two parallel runs of under floor duct they should be somewhat more frequent.

This is particularly true of a lighting current system as the Code permits only ten No. 14 wires in any one run of under floor duct between junction boxes. Hence lighting home runs should not be expected, regardless of conductor capacity, to serve more than five possible outlets in each direction from each box served by that particular feeder. General practice has been to space junction boxes from twenty to forty feet apart and provide feeders of 1 inch or 1¼ inch pipe for each separate system (lighting, telephone, low tension) at each box or at every other box. If possible connections to low tension cabinets should be duct.

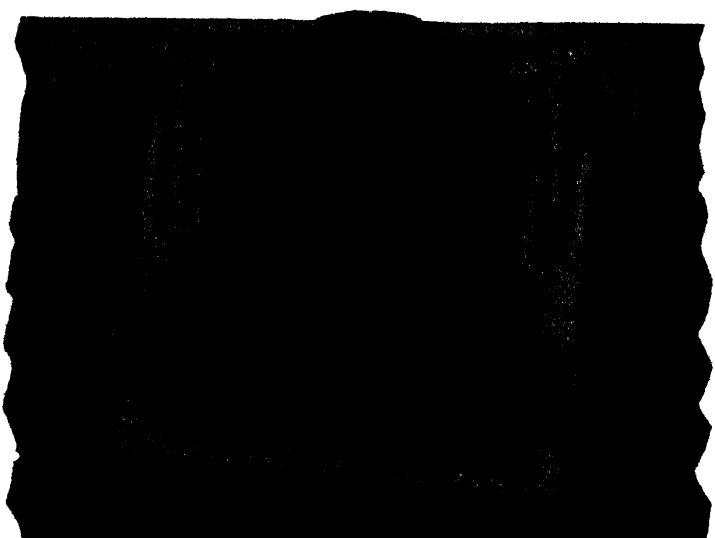
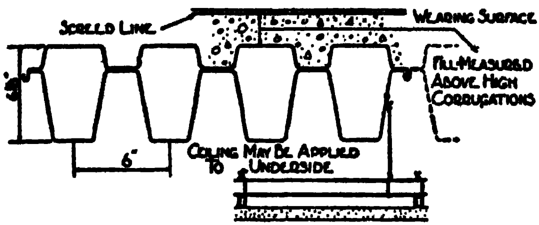


FIG. 5,712.—Fullman adjustable floor outlet. The box body is shown out of level which is the usual condition. The adjusting ring is set level with the finished floor line. Note how the adjusting ring *dips* into the groove deeper on the high side of the box body. When the cement in the groove of the box body hardens, the two parts are united just like a solid casting. The cover plate is in alignment with the finished marble floor. The brass flange ring protects the edge of marble floor from chipping upon repeated removal of cover plate.



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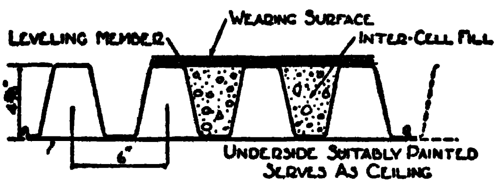

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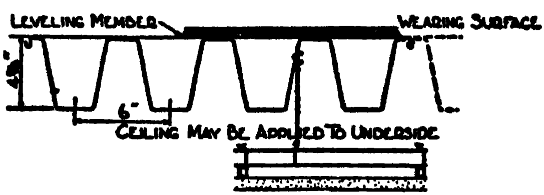

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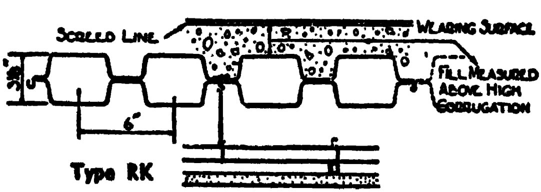

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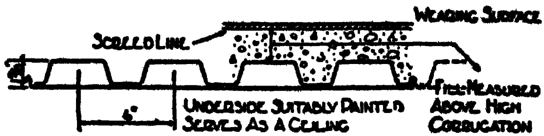
Figs. 5,712-1 to 5,712-4.—Showing cellular metal raceway construction suitable for various types of floor design. Cellular metal floor raceway is defined as the hollow space in metal floor framework where electrical conductors can be placed and is referred to in the National Electrical Code as a "*cell*".



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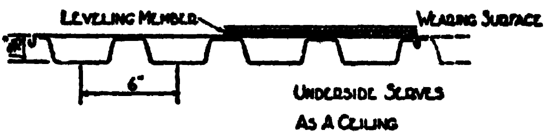


Type UK

FIGS. 5,712-5 and 5,712-6.—Cellular metal raceway construction suitable for various types of floor design.

TEST QUESTIONS

1. *Name two types of wiring systems for wiring under floors.*
2. *Describe a typical under floor system.*
3. *What name is given by the Code for under floor systems?*
4. *Describe under floor duct.*
5. *How is the duct installed?*
6. *Describe two types of plug used.*
7. *What must be done when a duct outlet is to be used for service?*
8. *Describe a surface extension.*
9. *Name the various fittings used with duct.*
10. *What kind of a fitting is used when an outlet is to be connected at the end of a duct?*
11. *Describe an under floor junction box.*
12. *Can any rules be given for making under floor layouts?*
13. *Name four classes of layouts.*
14. *Name an important factor to be considered in making a layout.*
15. *What spacing should be given to junction boxes?*
16. *How many wires does the Code permit in a single duct?*
17. *Must a layout necessarily take care of all possible conditions?*
18. *What are the features of under floor duct around outer wall arrangement?*
19. *Describe some typical under floor duct installations.*

20. *What should be considered in planning a round conduit system?*
21. *In under floor ducts should every outlet utilized have a separate circuit?*
22. *What is a home run?*
23. *How many outlets should be served by a lighting home run?*

CHAPTER 113

Wiring Under Plaster

For wiring under plaster extensions, the Code specifies that such extensions *shall be run in rigid or flexible conduit, armored cable, metal mouldings, or electrical metallic tubing of approved standard types.*

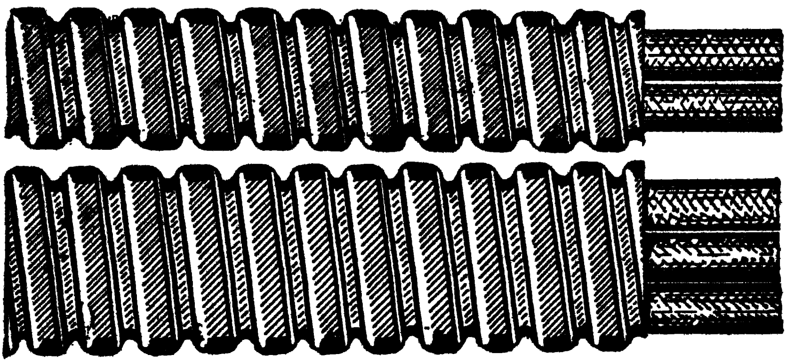
FIG. 5,713.—National "Ovalduct" flat under plaster raceway. *It consists of* a welded rigid tube, with an oval cross section 13/32 inch high x 31/32 inch wide, shallow enough so that it can be embedded in, and completely covered by plaster of ordinary thickness, when fastened directly to fireproof under body of concrete, tile or brick. Ovalduct is furnished in ten foot lengths, ten lengths to a bundle.

For under plaster work the various forms of flexible conduit are made flat or oval shaped so that when installed, the conduit will not project outside the surface of the plaster. National "Ovalduct" is an example of under plaster flat raceway. Its general appearance is shown in fig. 5,713.

For installations where close bends are required, such as dropping under exposed ceiling beams, or passing around projecting columns, on walls, and for fished work, a flexible or armored flat cable as shown in figs. 5,714 and 5,715 is used.

It is recommended that three wire flat conduit or cable be used instead of the two wire, because in many instances the third wire is required for switch control. When the two wire conduit or cable is used, it is necessary to install an extra run to carry the third wire when that wire is required.

Fittings and Outlet Boxes.—Flat raceway devices and fittings include a switch box 1½ inches deep, round outlet boxes ¾ inch deep, a sleeve coupling for joining two lengths of raceway or an elbow to raceway, a 45° flat elbow, a 90° vertical elbow, fastenings, and connectors which make it possible to extend flat raceway from any other type of raceway or wiring system.



FIGS. 5,714 and 5,715.—Flat armored cable for under plaster work. *Made* with three conductors in sizes 14 and 12; also with two conductors in sizes 14, 12 and 10.

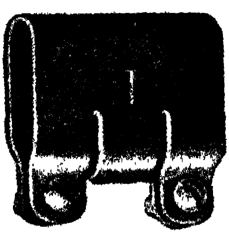


FIG. 5,716.—National squeeze type coupling.

FIG. 5,717.—National 90° elbow.

For joining lengths of flat raceway a coupling which slides over the raceway end is used, as shown in fig. 5,716. It makes a secure grounded connection when screws at sides are tightened. Joins two elbows, or raceway and one elbow in the same manner.

Fig. 5,717 shows a 90° elbow used for both external and internal angles. It is joined to the raceway or to a second elbow by the coupling shown in fig. 5,716. It also fits into connectors.

The 45° flat elbow shown in fig. 5,718 is also joined to the raceway or to a second elbow by the coupling.

The type outlet box used is similar to the ordinary box with exception that it is made shallow and has oval instead of round knockouts in the side, so shaped to fit the oval raceway or cable.

Fig. 5,719, shows a typical box.

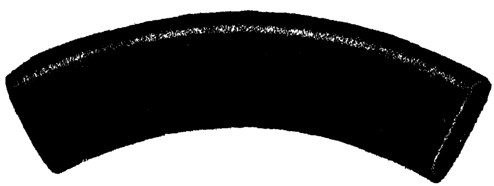


FIG. 5,718.—National 45° flat elbow.

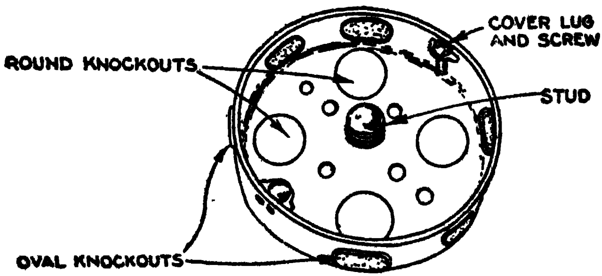
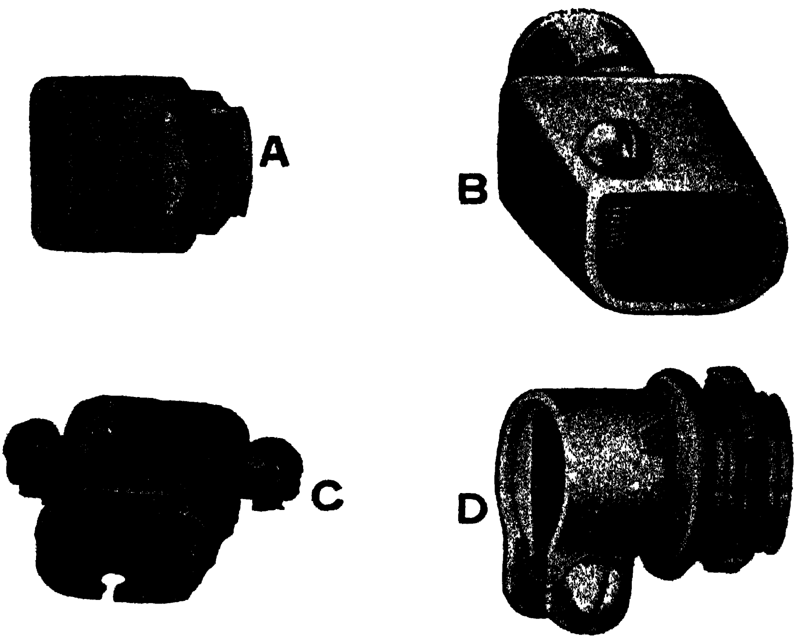


FIG. 5,719.—Shallow outlet box for oval conduit or oval armored cable. *Proportions*, $\frac{7}{8}$ inch deep overall. $\frac{3}{8}$ inch male fixture stud which is part of the box. Four $\frac{1}{2}$ inch knock outs in bottom and six oval knock outs in side spaced at 45°. Cover lugs and screws will take standard 4 inch round covers. Use oval connector.

Numerous types of connectors are shown in figs. 5,720 to 5,723.

Conduit Riser.—The most important unit of permanent conduit installation used in conjunction with easily changed ceiling and wall under plaster extensions of oval raceway or oval cable, is the *conduit riser*.



FIGS. 5,720 to 5,723.—National ctors. A, straight box connector, set screw type; B, cable box connector, set screw type; C, connector for metal moulding boxes; D, straight box connector, squeeze type.

This consists of conduit turned up from run in floor fill, into a convenience outlet 12 inches up the side wall or column, conduit extended thence up wall into permanent switch outlet located at usual height of 4½ feet from floor, and thence extended further up wall, terminating in junction or *pull box* near ceiling, as shown in fig. 5,728.

When *riser* is used with oval raceway extensions, a 90° vertical elbow is run into a knockout in uppermost wall of *pull box* with a connector which permits elbow to pivot.

This allows oval raceway ceiling extension to run in a straight line from the elbow to location of the nearest outlet. When a *riser* is used for oval flexible cable ceiling extensions, space above *pull box* being open for reasons stated, oval cable ceiling extensions are started directly from box connector inserted in top wall of *pull box*.

FIGS. 5,724 to 5,726.—National fastenings. Fig. 5,724, two hole fastening strap; fig. 5,725, two hole strap; fig. 5,726, wire toggle. The wire toggle is for fastening all sizes of oval armored cable to metal lath or tile. Insert toggle through hole, spread wire around the cable and twist with pliers. Twist wires at one side of cable to keep ends within plaster thickness.

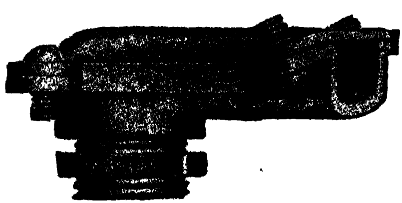
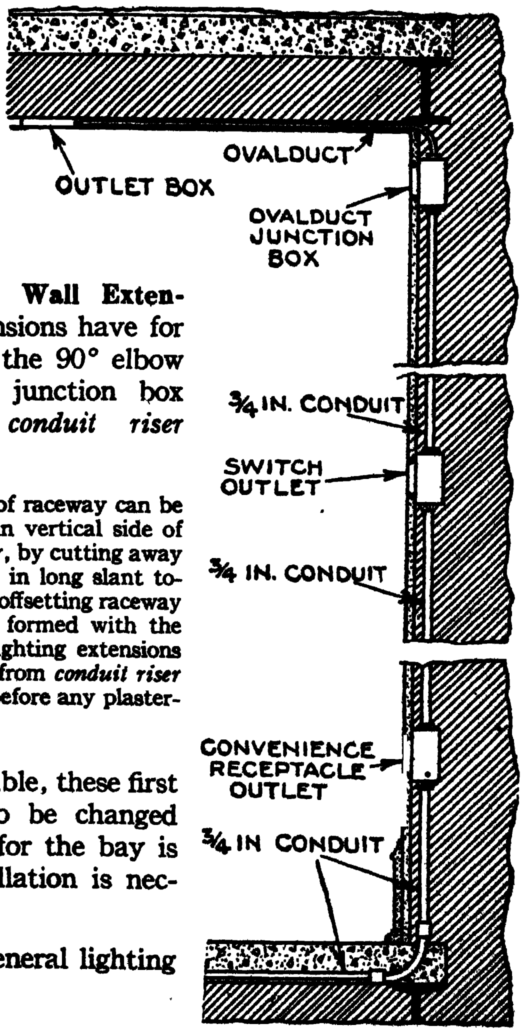


FIG. 5,727.—National 90° angle box connector. Will take oval raceway and elbows into ½ in. conduit knockouts or when used with pipe coupling, connects oval raceway and elbows direct to ½ in. conduit.

NOTE.—*It is recommended* that two *conduit risers* of the same kind as the one described, be installed diagonally from each other, in each bay of the office space under consideration. This avoids crossing oval raceway or oval flexible cable under dropped beams in ceilings, and locates permanent *riser* switch outlets and convenience outlets, so that the minimum number of extensions will have to be made, when partitions required by the tenant layout divide the space. *Conduit risers* should be located at points on walls or columns where dividing partitions are not likely to run vertically up wall with them, as this immediately renders permanent switch outlet and convenience outlet useless, and necessitates installation of extensions which might not have been needed had positions of *risers* been chosen more carefully.



Ceiling and Side Wall Extensions.—Ceiling extensions have for their starting point the 90° elbow fastened in ceiling junction box which terminates *conduit riser* shown in fig. 5,728.

Side wall extension of raceway can be run out of knockout in vertical side of any box of *conduit riser*, by cutting away under plaster material in long slant toward back of box, and offsetting raceway flatwise into angle so formed with the wall surface. Initial lighting extensions are run with raceway from *conduit riser* or *risers* in each bay, before any plastering is done.

Although it is possible, these first outlets may have to be changed when tenant layout for the bay is obtained, their installation is necessary

1. To give some general lighting arrangement for bay;

Fig. 5,728.—Conduit riser or starting point of under plaster wiring extension.

2. To provide lighting for a large space, in case dividing partitions are not required;

3. It is important as means of securing sufficient thickness of plaster over the entire space to conceal the raceway, so that when plaster is channelled in different locations for final

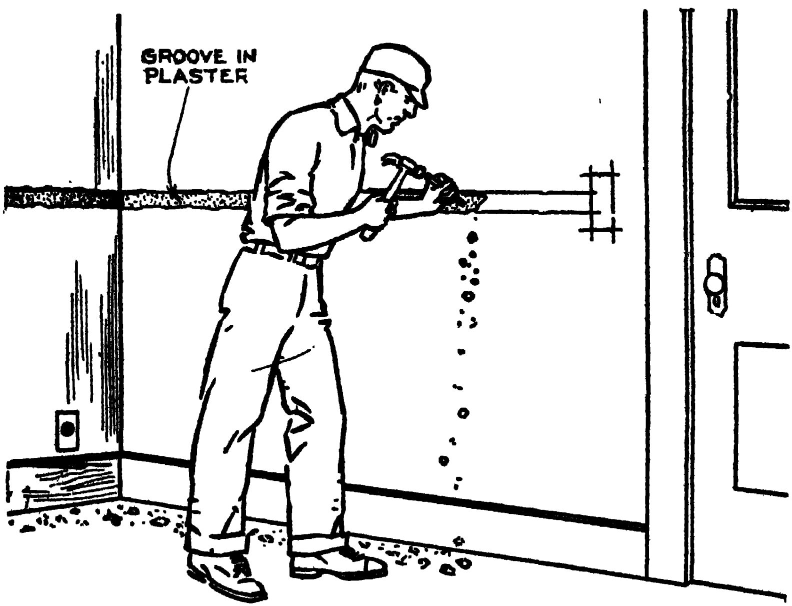


FIG. 5,729.—Method of channeling plaster groove for oval raceway or oval armored cable This operation is performed with a cold chisel and hammer, the channel limit front being marked as seen at the right.

lighting extensions, there will be ample plaster in which to embed the duct.

It should be noted, that when making any raceway or cable extensions, after plastering has been completed, only the plaster need be grooved. After duct has been laid in plaster groove, a little plaster patching is sufficient to cover it and restore original smoothness of ceiling.

For either oval raceway or oval flexible cable extensions, a 90° angle connector may be inserted in box knockout, and the raceway or cable extensions started from it. Two wire oval cable will require a smaller size connector of this type than the one suitable for both oval raceway and three wire oval flexible cable.

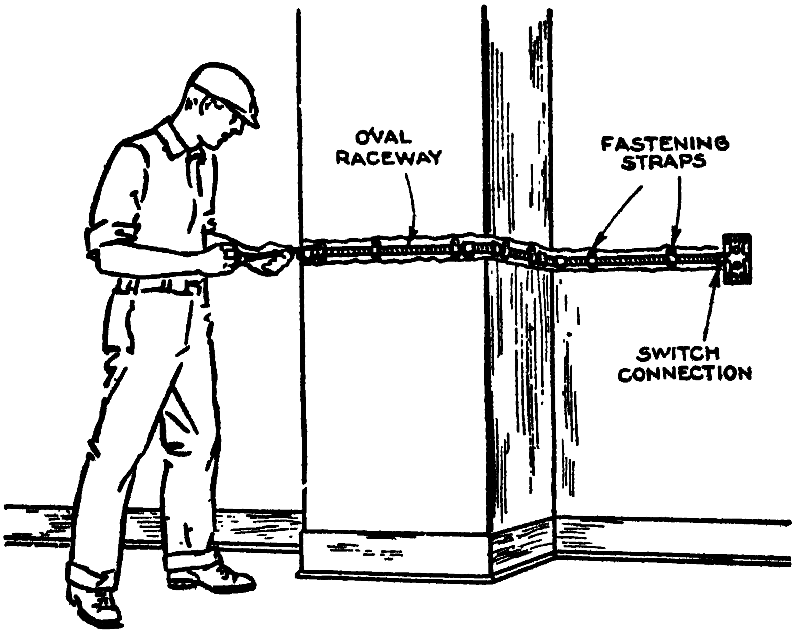


FIG. 5,730.—Method of fastening oval raceway with straps in channel cut in plaster. The illustration shows the end of the raceway joined to a switch box with a connector.

After installing the raceway, a fish cable is used in pulling in the conductors. Fig. 5,732 shows the operation of inserting the fish cable in the raceway and fig. 5,733, detail of fish cable.

Instead of using elbows, turns are frequently made by bending the raceway as shown in fig. 5,734.

If the bending be carefully done, the raceway will not be distorted. While it is possible to bend the raceway flatwise, this requires special tools and equipment, in order to retain proper cross sectional dimensions, hence the practice is not recommended for the field. Because of the complicated method which must be followed, the manufactured flat elbow as shown in fig. 5,718 is generally used for flat bends.

FIG. 5,731.—Method of fastening oval raceway with wire toggle to lath.

NOTE.—*The thickness of plaster* and of lath and plaster in installing under plaster wiring should first be determined. Formerly the thickness of plaster and lath was about 1 inch, but the practice now is to cut the thickness down as much as possible and in some cases of unscrupulous contractors it requires a stretch of the imagination to regard it as plastering. Accordingly, before attempting to install under plaster wiring the thickness of the plaster should be determined. To install under plaster wiring, the plaster is first channeled out from conduit riser outlet to end of the extension. Fig. 5,729 shows this operation. After the channel is completed from the riser outlet box to the end of the extension, the raceway is fastened in the channel with straps as shown in fig. 5,730. For a ceiling extension the raceway is fastened with

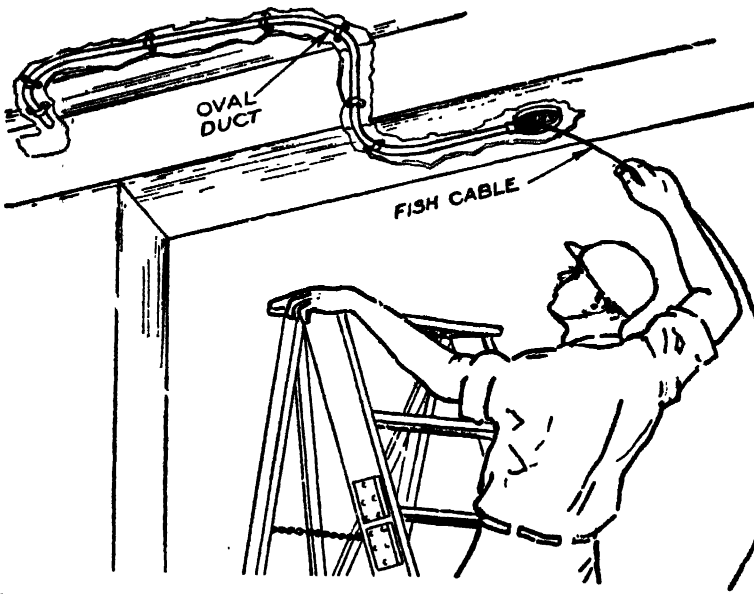


FIG. 5,732.—Method of inserting fish cable in raceway.

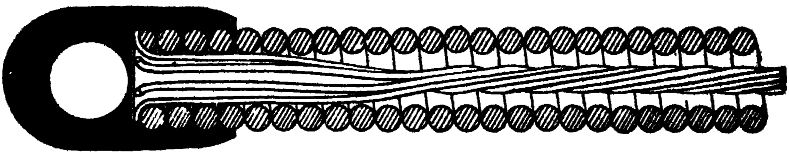


FIG. 5,733.—National fish cable used for pulling in conductors in oval raceway. *It consists of* stranded cable of piano wire enclosed in outside helix of the same material; ends of both stranded cable and outside helix are fastened securely into heads, or eyes at each end. It is tested to 350 lbs. pull. When it is pushed through raceway, wires can be attached to specially shaped head, or eye, at either end, and pulled through raceway, without use of usual cord. This cable is made flexible enough to fish through 5 elbows. Attach conductors directly to end eye of cable.

NOTE.—*Continued.*

a wire toggle as in fig. 5,731. This toggle is shown in detail in fig. 5,726. The extension in fig. 5,731 passes through a partition and is joined at its end to an outlet box, as seen through the transom. This box is ⅝ inch deep and its edges should be flush with the surface of the plaster.

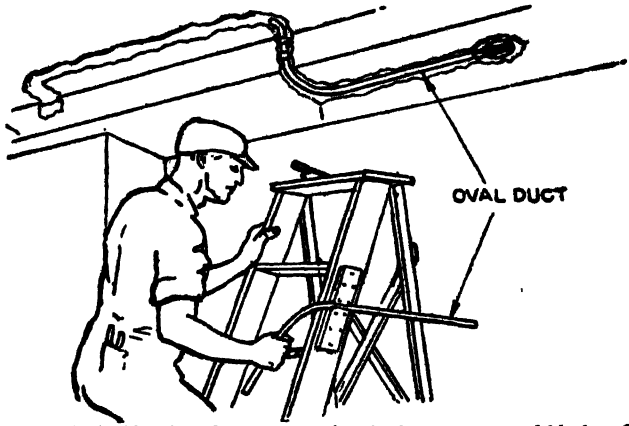


FIG. 5,734.—Method of bending flat raceway edgewise between grooved blocks. Two wood blocks are secured to step ladder or work bench, with grooved ends adjacent, to hold raceway during bending operation. They are mounted with sufficient space between to allow for insertion of raceway from the side, which eliminates awkward operation of sliding raceway lengthwise through groove. After the raceway has been inserted in groove between blocks, it can be bent to any desired radius and degree of angle at any point in the length, by exerting downward pressure on it in short *hitches*.

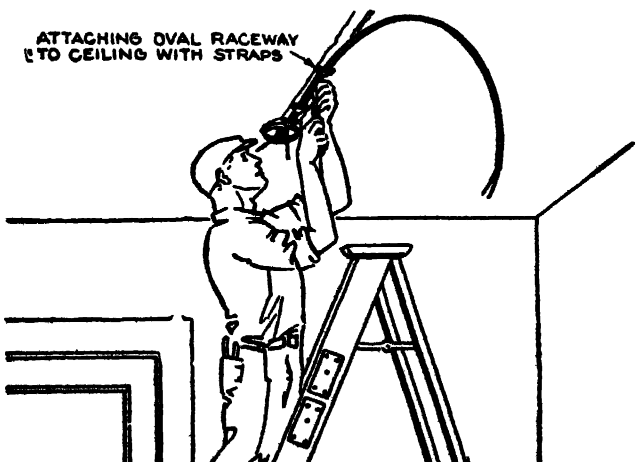


FIG. 5,735.—Method of fastening flat armored cable in plaster groove on concrete ceiling. Note connection of the cable with outlet box.

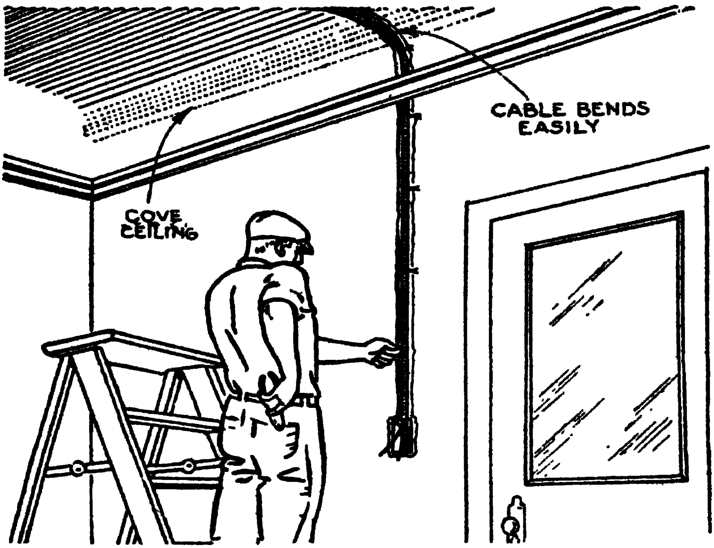


FIG. 5,736.—Oval cable installed on cove ceiling illustrating its flexibility.

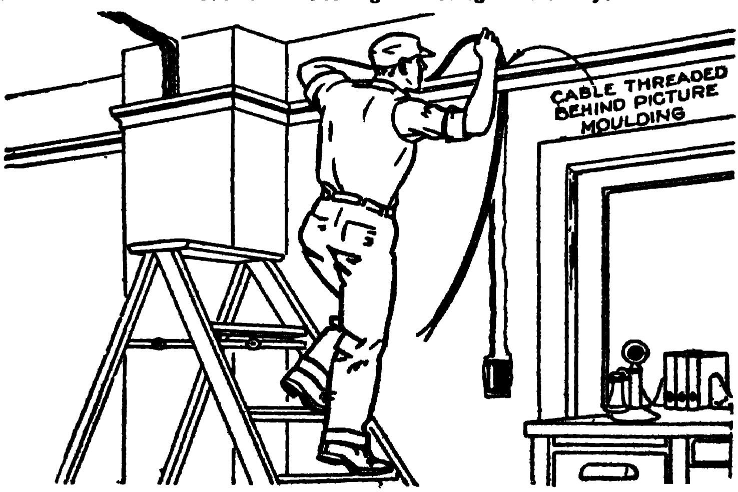


FIG. 5,737.—Oval cable run horizontally behind picture moulding with sharp bends.

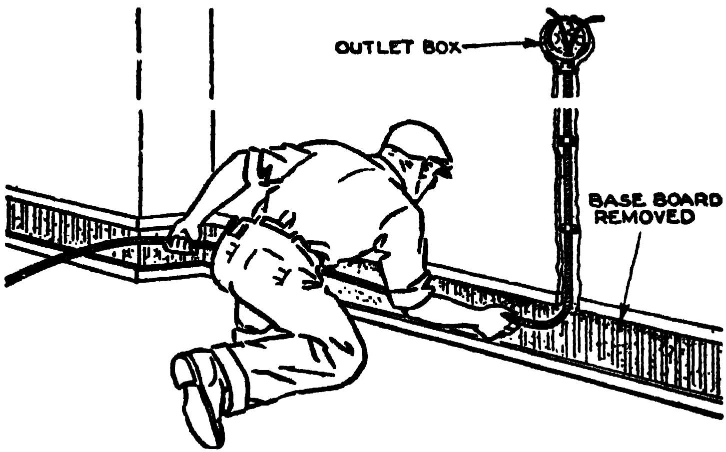


FIG. 5,738.—Oval cable run behind baseboard.

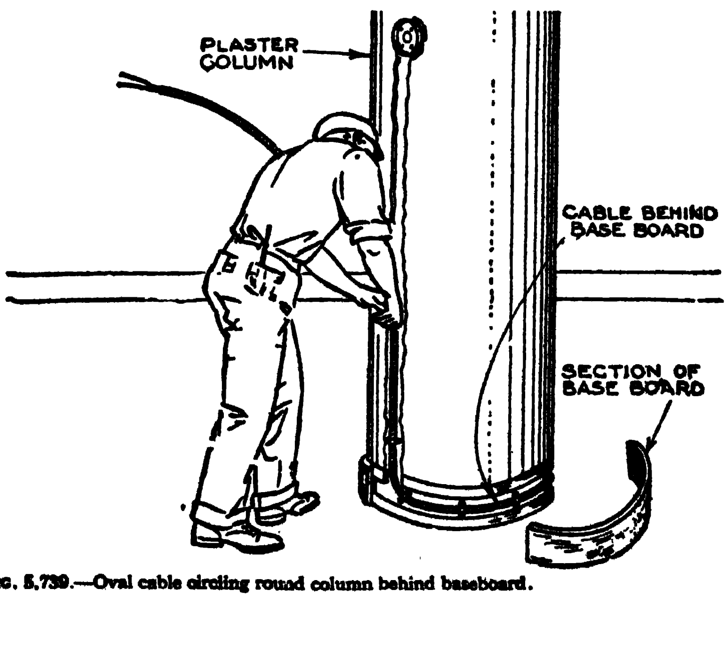


FIG. 5,739.—Oval cable circling round column behind baseboard.

Under Plaster Extensions with Flat Armored Cable.—This flat cable, shown in figs. 5,714 and 5,715 is very flexible and is embedded in plaster in the same manner as described for flat raceways. It renders lighting installations subject to easy change for tenant requirements. Same shallow fittings are used, excepting a few items, and are interchangeable for both wiring materials.

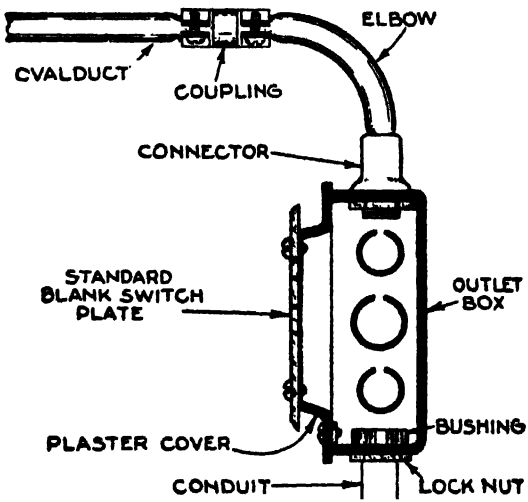
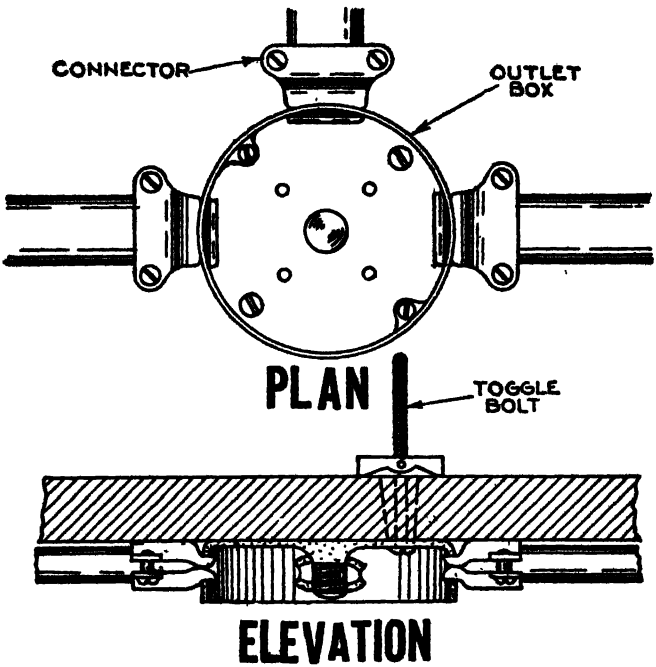


FIG. 5,740.—Outlet box at end of conduit riser, showing connection with oval raceway by of a connector, elbow and coupling.

In conjunction with *conduit riser* shown in fig. 5,728 ceiling extensions of oval cable in office bay are started from straight or 90° angle connector inserted in top knockout of *riser* ceiling junction box. Side wall extensions of oval cable can be started from side knockouts of any *riser* box by cutting away enough concrete or tile at side of box. to allow room for oval cable to be bent into a straight box connector fastened in a side knock out of box.

Two applications of oval cable are shown in figs. 5,736 and 5,737, which avoids bending or use of fittings as would be necessary with raceway wiring.

In the operations shown in figs. 5,738 and 5,739 it is seen how much time is saved due to the flexible cables. Wire toggles may be used for fastening



FIGS. 5,741 and 5,742.—Connection of extension branch to extension run of raceway with outlet box, also method of fastening the box on tile with toggle bolt.

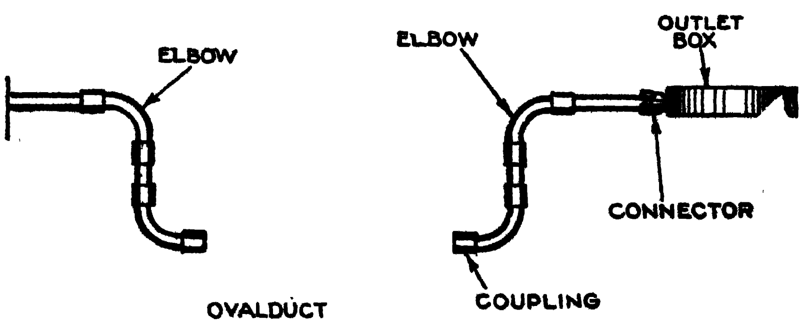
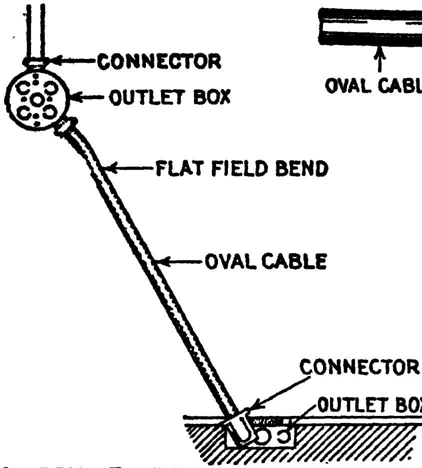


FIG. 5,743.—Offset made in oval raceway by means of fittings.



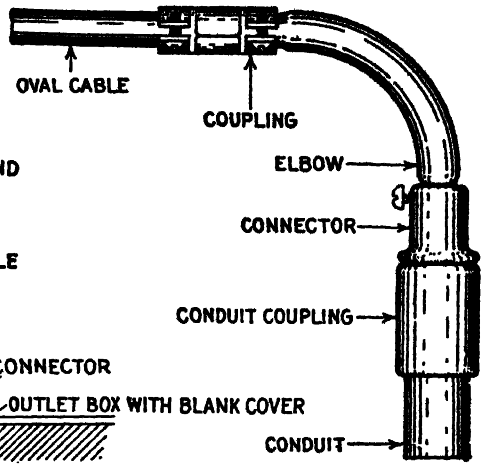


FIG. 5,744.—Two lighting outlets served from the same junction box.
FIG. 5,745.—Oval raceway ceiling extension connected directly to conduit riser.

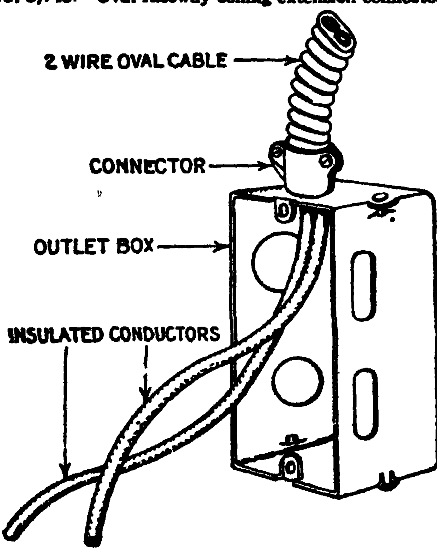


FIG. 5,746.—Oval armored cable switch box installed with switch leg of two wire oval cable.

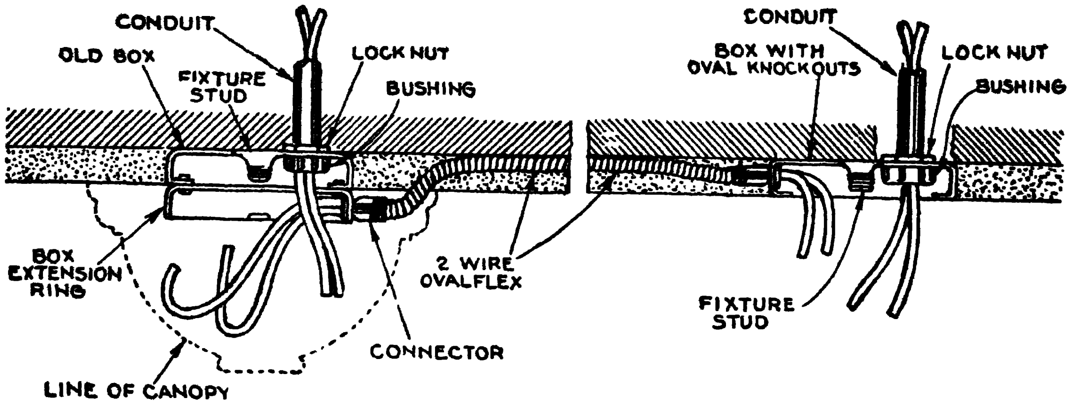


FIG. 5,747.—Oval armored cable extended from au old outlet to serve a new outlet shown at the right of cut. At the left is an extnsion ring mounted on box left in ceiling. This method may be used only when the box is 4 inches in diameter, and the canopy is large enough to cover portion of oval cable projecting out of plaster. To extend oval cable from old outlet box embedded in concrete ceiling, remove the plaster, raise cover, and substitute for it an extension ring when box is 4-inch octagon or round· or substitute a cover having oval knockouts, when box s 4-inch square.

oval cable to tile, wire lath, and under plaster surfaces of similar construction. Straps of one or two screw type with expansion screws or wood plugs, are intended for fastening the cable to under plaster surfaces of concrete or brick. Some contractors prefer to drive case hardened nails into concrete to secure straps, instead of screws and expansion shields.

Number of Conductors in a Box.
DEEP BOXES

Box Dimensions Trade Size	Maximum Number of Conductors No. 14	No. 12	No. 10	No. 8
1½ x 3¼ octagonal..	5	5	4	0
1½ x 4 octagonal	8	7	6	5
1½ x 4 square	11	9	7	5
1½ x 4 11/16 square .	16	12	10	8
2⅛ x 4 11/16 square .	20	16	12	10
1¾ x 2¾ x 2	5	4	4	
1¾ x 2¾ x 2½	6	6	5	
1¾ x 2¾ x 3	7	7	6	

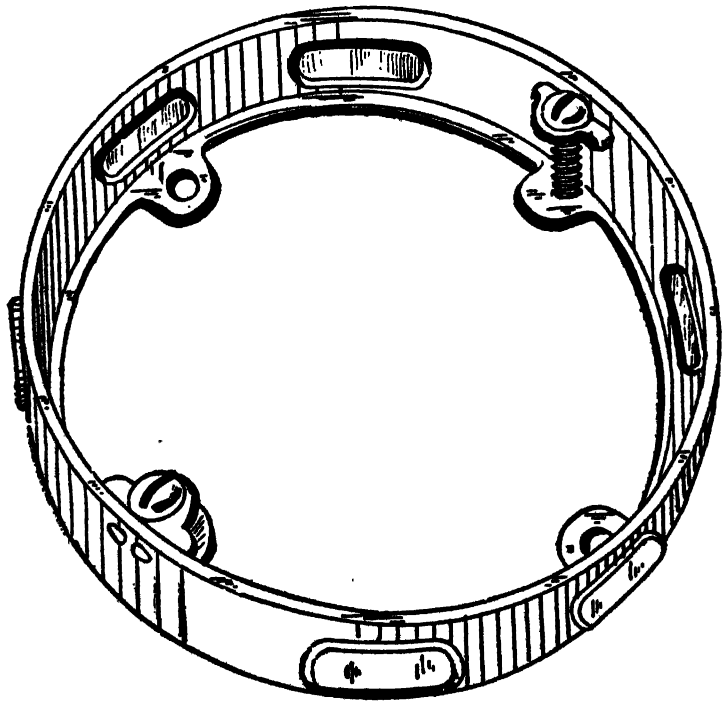


FIG. 5,748.—National extension ring for Ovalduct. 4 in. diameter, ¾ in. deep over all. Six oval knock outs in side spaced at 45°. Will fit any 4 in. octagon or round box and is provided with four fastening lugs to permit turning the ring in line with Ovalduct runs. Cover lugs and screws will take standard 4 in. round covers.

TEST QUESTIONS

1. *What are the Code requirements for wiring under plaster?*
2. *What form of conduit is used for under plaster work?*
3. *What should be used for close bends?*
4. *What kind of fittings are used?*
5. *Describe the squeeze type coupling.*
6. *Describe the kind of outlet box used for oval armored cable.*
7. *Describe a conduit riser.*
8. *What kind of a fitting should be used when riser is used with oval raceway extensions?*
9. *When should two conduit risers be used?*
10. *Give the method of channeling plaster grooves for oval raceway.*
11. *How is the raceway fastened in the groove cut in the plaster?*
12. *Give the method of inserting fish cable in raceway.*
13. *How is flat raceway bent edgewise?*
14. *What is the method of fastening flat armored cable in plaster?*
15. *What kind of fittings are used for under plaster extensions with flat armored cable?*
16. *Describe the method of connecting an outlet box at end of conduit riser.*
17. *What is the method of fastening an outlet box on tile?*
18. *How is an offset made with oval raceway?*
19. *Give sketch showing two lighting outlets connected to the same junction box.*

20. *Make layout showing oval raceway ceiling extension connected direct to conduit riser.*
21. *How is a switch box for oval armored cable installed?*
22. *Make a sketch showing oval cable run behind baseboard.*
23. *How is oval cable run behind picture mouldings when there are sharp bends?*

CHAPTER 114

Remote Control Wiring

A comparatively recent method of residential electric wiring system known as *remote control wiring* has been introduced by the *General Electric Company*.

With reference to figs. 1 to 4, showing typical circuits, the heart of the system is a single-pole, single-throw, double-coil relay, which coil is operated from a low voltage source as indicated.

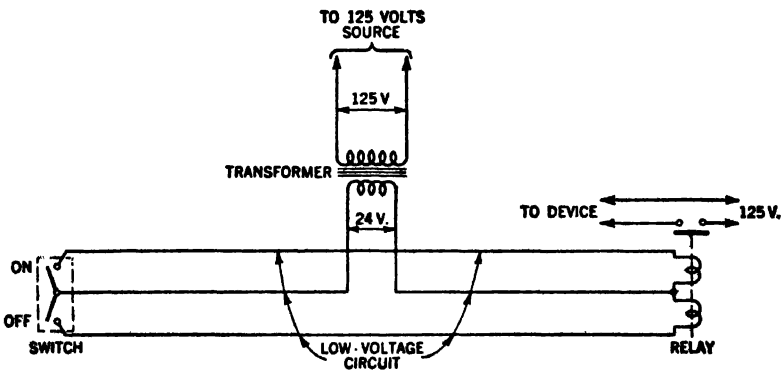


FIG. 1.—Schematic diagram of remote control wiring circuit showing one relay controlled from one switch.

Essentially, low voltage residential control switching provides for turning lights and appliances *on* and *off* remotely either within a house, its surroundings grounds, or other buildings on the property.

The remote control house wiring system provides the same advantages, economies, and ease which characterize the use of magnetic controllers for motors whereby large blocks of power may be remotely controlled by closing or opening the circuit of the contactor coil.

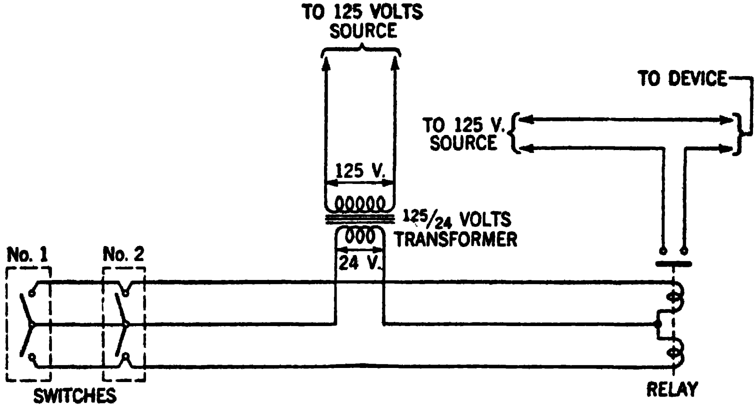


FIG. 2.—Schematic diagram of remote control wiring circuit showing one relay controlled from either one of two push-button stations.

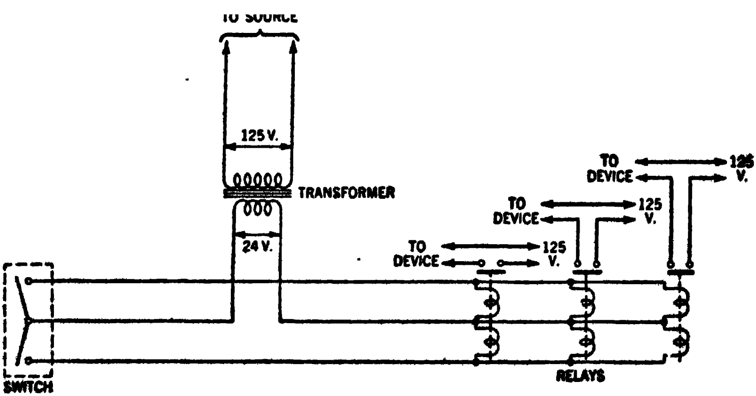


FIG. 3.—Schematic diagram showing a number of relays controlled from a single push-button station.

In meeting the applicable requirements of the *National Electrical Code* and the *Standards of Underwriters' Laboratories, Inc.*, use has been made of low voltage control circuits with the economies in wiring cost and added safety which are afforded by the use of low voltage.

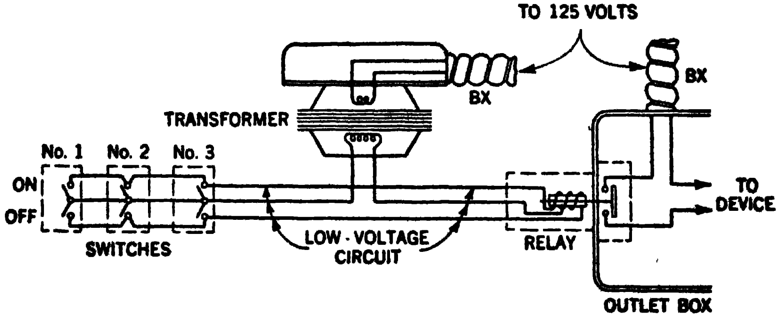


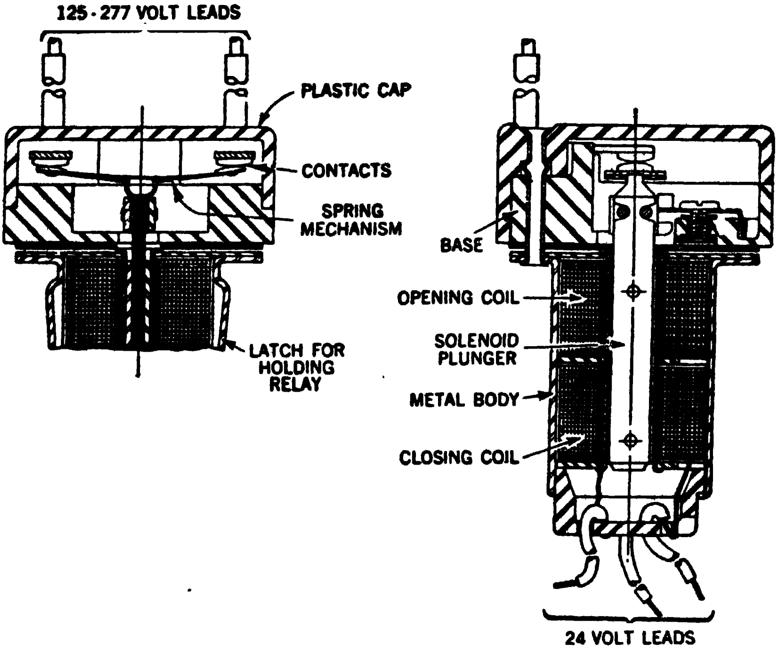
FIG. 4.—Pictorial wiring diagram illustrating one relay controlled from any one of three push-button stations.

Relay Unit.—The fundamental item of this remote control wiring scheme is a single pole, single throw, double coil relay, illustrated in figs. 5 and 6.

The relay contacts are operated by momentarily energizing either the opening or the closing coils. The contacts remain latched in either the opening or closed position with no further application of control power.

The coils are designed for low voltage operation from a standard remote control power supply. The relay is unusual with respect to its mounting arrangement in that three requirements are met by a single design feature. As will be observed in figs. 5 and 6, the operating coils and magnetic structure are enclosed in a metal barrel on which is mounted an insulating chamber, housing the contact structure and the detent action. This design provides the following features:

1. The relay is mounted by inserting the metal barrel through a one-half inch knockout in a standard outlet box or other metal enclosure. Spring actuated dogs hold the relay in position when installed.



FIGS. 5 and 6.—Showing contact arrangement and operating mechanism of remote-control relay.

2. When installed as indicated in fig. 7, the necessary physical separation of the power circuit and the control circuits as required by the *National Electrical Code* is automatically established with the power circuits confined in the metal enclosure of the raceway, and the control circuit isolated by being on the outside. The same result is obtained when the relays are mounted in one-half inch knockouts or holes in metal barriers in appropriate metal cabinets which have both high and low voltage requirements.

3. Equipped with flexible leads, the relays can be easily removed for inspection, maintenance or reconnection.

Relay Contact Structure and Detent Mechanism.—The contact structure and detent mechanism is an adaptation of a standard precision snap-acting switch design selected for extremely long mechanical life. The contacts are of silver and are rated 15 amperes at 125 volts *a.c.*, 5 amperes at 277 volts *a.c.*; one-third *hp.* at 125 volts *a.c.*

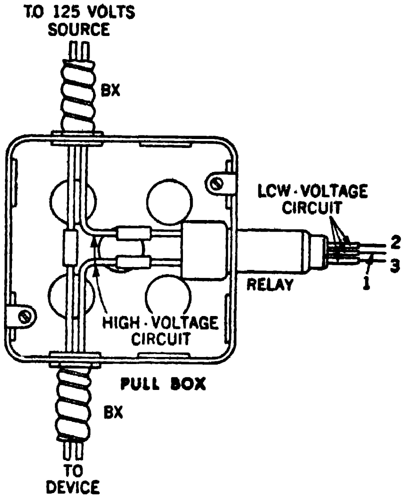


FIG. 7.—Illustrating remote-control relay mounted in outlet box.

The 15-ampere 125-volt, *a.c.* rating is approved for tungsten filament lamp loads. At both the 15-ampere 125-volt *a.c.* and 5-ampere 277-volt *a.c.* ratings, the relay will handle its rated current of fluorescent lamp ballasts, the 50 per cent current derating factor for inductively-loaded snap switches does not apply.

Power Control Source.—Control power for the remote control wiring system is in accordance with the requirements of Article 725 of *The National Electrical Code.* Under these

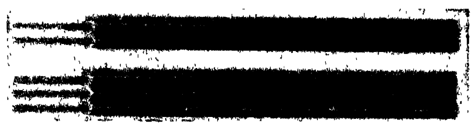
regulations, a remote control or signal circuit system in which the potential is limited to 24 volts and the maximum current limited to three amperes is excluded from compliance with many of the requirements for standard branch circuit wiring used at normal utilization potentials.

FIG. 8.—Typical high-reactance 125/24-volt transformer, used in remote-control wiring system.

The power source is a 125/24-volt, high-reactance transformer listed by the *Underwriter's Laboratories, Inc.*, for this service. This transformer, shown in fig. 8, may be short-circuited continuously at its 24-volt terminals without exceeding its rated temperature rise, and the short-circuit current is within the limits required in the *National Electrical Code.*

The low voltage wiring is not required to be in conduit or to be a listed raceway material, such as armored cable, it is only required that it be physically separated from the power wiring, unless insulated for the full voltage of the power conductors.

Control Wire.—Designed specifically to be used in this system is a two- or three-conductor low-voltage control wire insulated with type TW *thermoplastic*, shown in figs. 9 and 10. The conductors can be separated by tearing the web of insulation holding the assembly together, as is done with the well-known rip cord used on portable appliances and lamps.



FIGS. 9 and 10.—Low-voltage control wire suitable for indoor and outdoor u

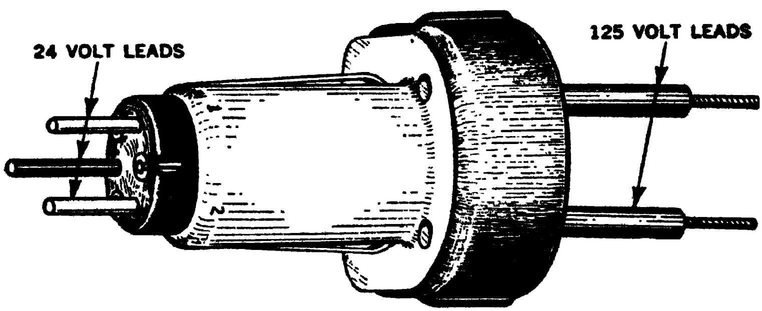
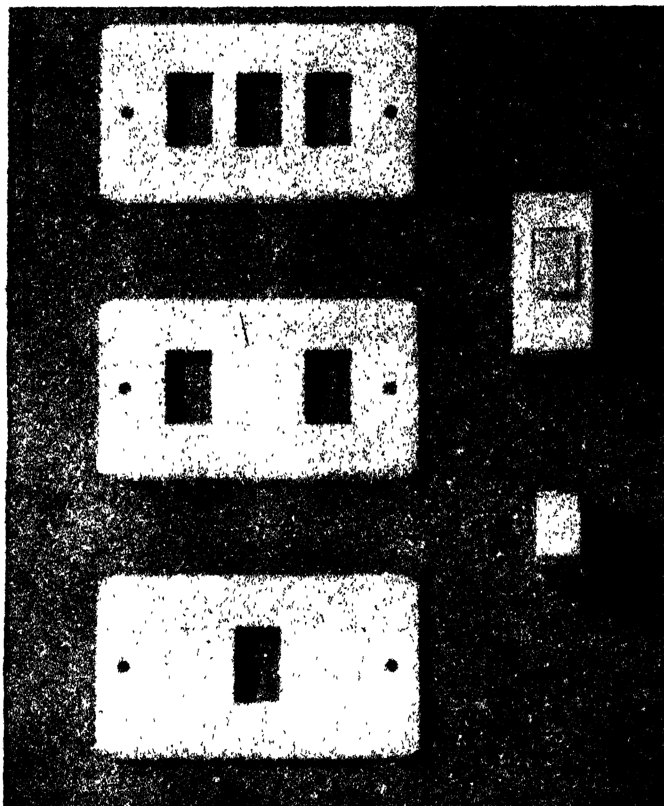


FIG. 11.—Exterior view of control relay. This relay is actually a two-coil solenoid operated switch, in that when a coil is energized by pushing the switch *on-off* button, the solenoid plunger moves, opening or closing the 125-volt circuit. The 125-volt solenoid contacts are held open or closed unless moved by solenoid action.

An ingenious use of ribbing on the conductors serves as identification. The wire is suitable for all interior or dry locations and may be installed in raceways when desired.

A similar wire with 3/64 inch insulation of *Neoprene* is used for direct earth burial or for any out of door or exposed locations. When installed overhead, it is suspended from any appropriate messenger wire.

Control Switches.—Because either of the two coils of the relay, fig. 11, requires only momentary application of energy for operation, the minimum control unit for one relay is a single-pole, double-throw momentary contact switch or push button.



Figs. 12 to 16.—Illustrating one-, two-, and three-gang wall plates and low voltage flush-mounted and surface-mounted switches for controlling relays.

Figs. 12 to 16 shows the several forms in which such a switch is available for the remote control system. Because these control units are used in the 24-volt circuit, they are excluded from compliance with many of the requirements that are applicable to conventional snap switches in lighting circuits.

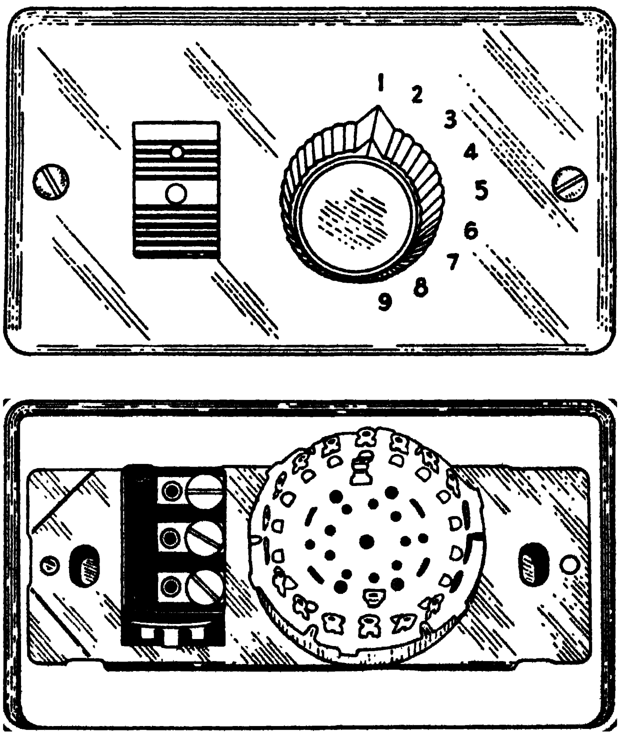
The basic unit made up of the operating button, the contact structure, the necessary terminals, and mounting brackets, is used in several different assemblies for various applications.

In one form, it is a surfaced-mounted unit, suitable for mounting on either insulating or conducting surfaces. It can be used on metal door frames or metal desks, directly on all types of walls or interior building surfaces, and will accommodate both exposed and concealed wiring.

The same basic unit is available for mounting in conventional switch boxes in single, double or triple units. For flush mounting, the switch element can be supported by any of a variety of brackets because the enclosure provided by boxes is not a requirement. The use of a switch box, however, is a practice well known to electricians and, because boxes are relatively inexpensive, this is a popular method of installation.

Master Selector Switch.—One of the advantages of remote control is the ease with which multipoint switching may be obtained. This advantage facilitates the collection of a number of switches at one point, a condition which has been recognized in the design of the master selector switch shown in figs. 17 and 18. Here the master switch provides means for operating each relay independently or for operating a maximum of nine relays in one operation. This latter switch is designed for flush mounting and is essentially a transfer switch serving to connect in sequence a regular control switch into the circuit of each relay to be operated.

Operational Features.—The various system components taken together in a great variety of combinations, comprise the application theory of the remote control system. To understand why this system is used and its advantages over conventional wiring methods, the following points should be considered:



Figs. 17 and 18.—Showing front and rear view of typical master selector switch.

1. In the remote control system the power wiring does not run to the control location as with conventional switches where all of the controlled energy has to flow through each switch location.

2. The relay can be located at the lighting outlet, or at any point selected, to reduce the length of the power wiring to straight runs from the panel board to the fixtures.

3. Multi-point control is obtained by simply connecting additional single-pole, double-throw control switches in multiple. There is no limit to the number of switches which can be used to control a single relay.

4. Since the relays require only momentary energizing for their operation, a single transformer is sufficient to supply control power for a large installation.

5. As many as four relays, their coils wired in multiple, can be operated simultaneously from a single control switch. This characteristic of the remote control system which permits control of loads in separate branch circuits is not available in conventional systems.

6. Positive identification of the switching operation is obtained because the same side of each switch always means *on* and the other side *off*. In conventional three-way and four-way installations, the switch trigger is not significant, and hence conventional switches are non-indicating.

7. Relays can be controlled from distances as remote as 1,500 feet a condition not generally practical with standard wiring because of voltage drop.

8. The use of 24 watts in the control circuit is a safety factor. This is of great importance in the use of elevated distribution voltage for flourescent lighting.

9. Remodeling, relocation of partitions, and rewiring generally are simplified by using the remote control low-voltage switching components.

10. Controls are small in size and their shallow depth aids in installation in thin partitions.

11. The circuits are simple and no more complete electrical layout is required by the contractor than with a conventional system.

12. The 277-volt, five-ampere rating permits the relay to be used in 480Y/277-volt distribution for flourescent lighting.

13. The installed cost of the remote control system is comparable to systems using conventional material.

14. The simple master switch provides a new concept in lighting control, the application of which is limited only by the ingenuity of the engineer or architect.

15. The components in their simplest form are usable in frame construction and surface wiring. In fire resistant construction, similar economies

are available, because there are savings in conduit, building wire, labor, and maintenance. With proper fittings, the system can be used out of doors and even in hazardous locations.

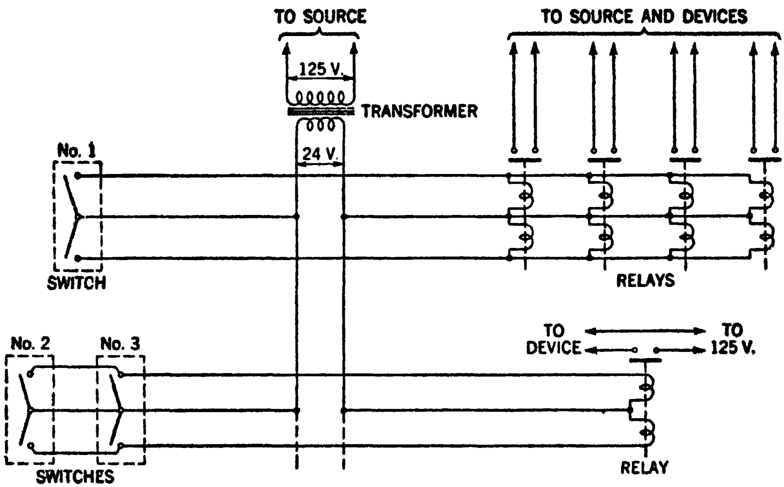


FIG. 19.—Wiring diagram showing method of transformer connection for two or more branch circuits.

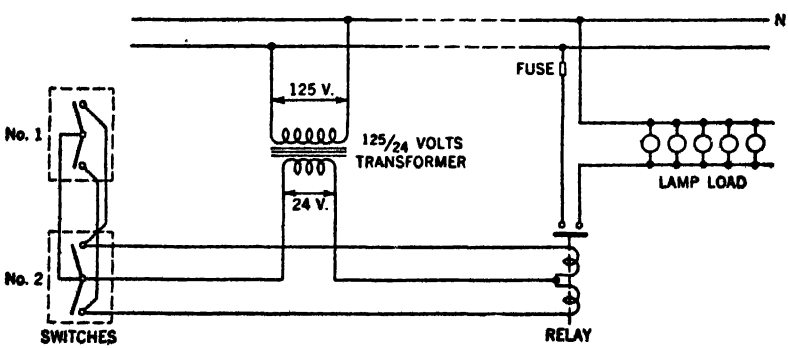


FIG. 20.—Wiring diagram illustrating how a group of lamps may be controlled from either one of two push-button stations.

16. This system is completely compatible with conventional systems, and either one can be used to complement the other.

17. The economies in the use of remote control increase as the use of multi-point control increases.

18. In addition to the savings and obvious advantages of this system, architects, contractors, and builders have used it as a new sales feature, which has been sought for many years to direct attention to the need for good wiring.

19. Although the remote control relay is not intended to serve the functions of either manual or magnetic motor control, it is a much more satisfactory control device for those equipments, such as attic ventilators which heretofore have been operated from motor snap switches.

20. All of the components are designed for use in combination with existing standard wiring materials in agreement with applicable *Codes* and *Ordinances*. These new components are marketed through existing distribution and sales channels, a feature which has been lacking in the promotion of many otherwise splendid developments in the construction materials field.

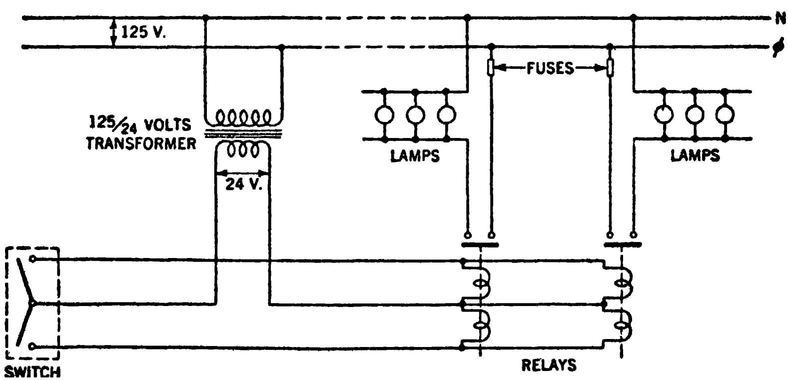


FIG. 21.—Wiring diagram illustrating how two groups of lamps may be controlled from a single push-button.

Applications.—To illustrate the use of the remote control wiring system, only a brief mention need be made of its use in industrial occupancies. The use of protective lighting is so

well established in industrial areas that its use in private homes is worthy of consideration.

With a remote control master switch at the bedside, it is a simple matter to illuminate the house, including porches and

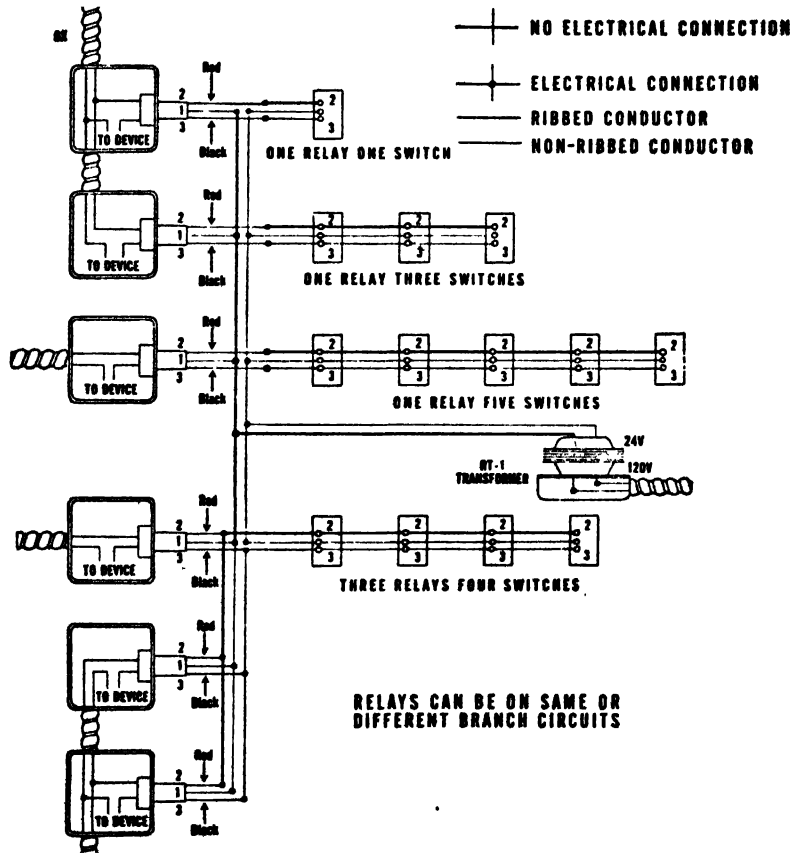


FIG. 22.—Diagram showing connection methods in a remote control wiring system having several branch circuits, each with a different number of switches and control relays.

garage, whenever it is believed that intruders are about. To the housewife who may be alone at night, this is particularly comforting.

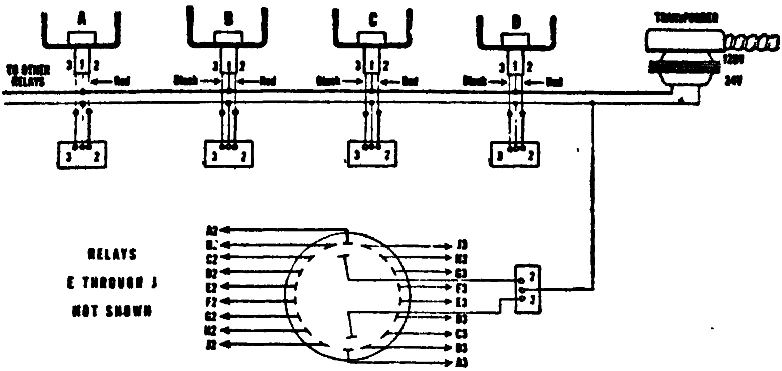


FIG. 23.—Illustrating typical wiring method for master selector switch. With the master selector switch it is possible to control any one of nine circuits independently or for operating all circuits simultaneously. To control individual circuits, it is only necessary to turn selector switch to circuit desired, then press control switch for *on* or *off* as desired. To control all circuits, press control switch for *on* or *off*, while turning selector switch through full sweep of all nine positions.

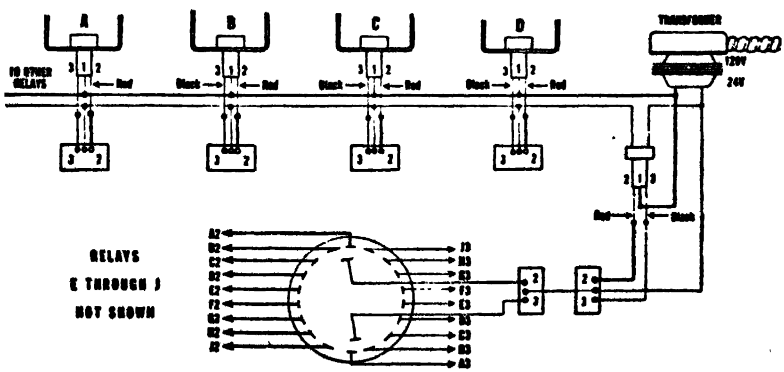


FIG. 24.—Remote control wiring hook-up showing connections to master selector switch with lock-out circuit.

It is likewise desirable to be able to walk into a fully-lighted house by having master switches in the garage and at the entrance to the house.

With this availability of multi-point control, it is now a simple matter to locate switches at each doorway in every room so that there may be a pathway of light in every room throughout the house.

Many special applications have been made to attic ventilators, to a bathroom heater circuit controlled from the bedside, to the radio outlet from the telephone location, to the front door or garage light from the kitchen and to countless other uses that may suggest themselves.

Farm Use.—To all the applications which may be made in the home, many more are added on the farm and in the farm home. On most modern electrified farms, a yard light on a central pole is the farmer's own street-lighting system.

With remote control, he can turn his lights *on* and *off* from the farmhouse, from his bedside, from the barn, or from any building on the farm, and even from the gate at the highway. The barn lighting can be controlled from each entrance to the barn and from the farmhouse.

Industrial Use.—In industry generally the applications are limited only by the extent to which controlled light is desired. With remote control, it is possible to set up selected lights for watchman's circuits and to control these circuits from the different entrances by which the watchman enters and leaves the area. Stockroom lights, always left on, can now be controlled from the stock-keeper's desk.

Protective yard lighting and general purpose yard lighting can now be controlled from the guard office or other central location, a valuable feature in bad weather.

A few strategically located master switches for turning off all lights in any kind of factory or business establishment is assurance that these lights will be turned off at closing time.

Similarly, for hospitals, schools, theatres, motor courts, bowling alleys, super-markets, athletic arenas, illuminated signs, and on through the entire use of electric lighting these applications are multiplied.

Office Use.—The most recent and probably the most spectacular application of the system is to office building lighting. The economies of 480Y/277-volt distribution for power and light are well established but have been blocked by the lack of a suitable switch for controlling the small amount of power required for lighting individual offices.

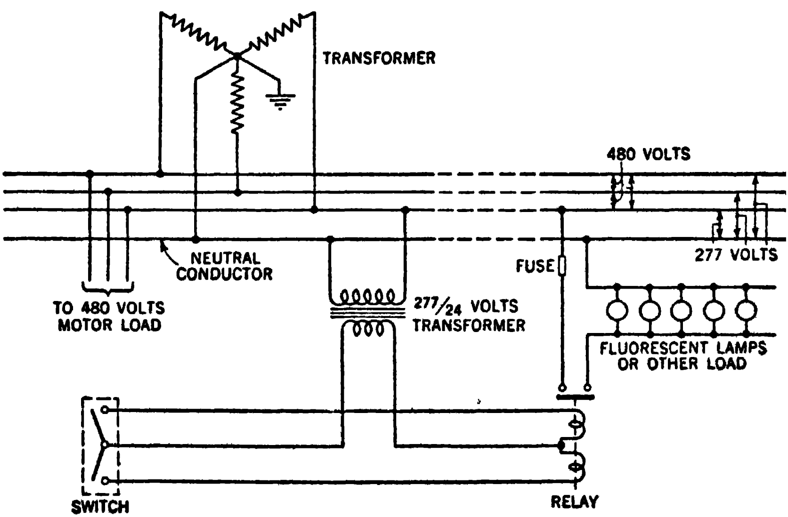


FIG. 25.—Illustrating method of lamp control in a high voltage distribution system. Here high voltage lighting circuits are incorporated in a 480Y/277-volt, three-phase, four-wire distribution system in which motors are connected at 480 volts line-to-line and fluorescent lamps at 277 volts line to neutral.

The key that opens the door to the use of higher potentials in office distribution systems is the remote control relay with its 5-ampere 277-volt rating.

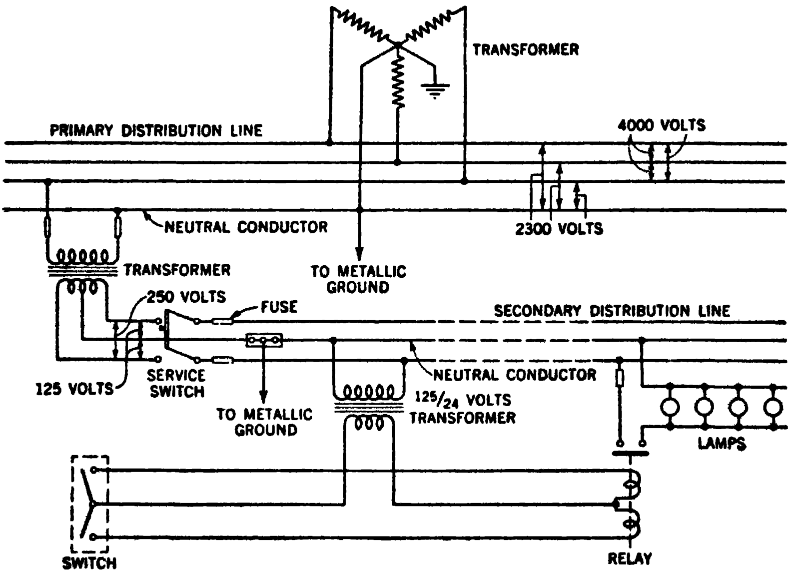


Fig. 26.—Showing transformer connections and remote control wiring in typical power distribution system.

Conventional snap switches have a maximum rating of 250 volts. Switches rated 251-600 volts are too large and costly for general office use, and magnetic or manual motor controllers are similarly not suitable.

The industry's objection generally to the 480Y/277-volt system has been the hazard of higher voltage. Now with remote control, the lights are safely controlled from 24-volt switches.

Installation Procedure

The installation of electrical wiring and equipment shall conform with the requirements of the *National Electrical Code*, existing Municipal and State Codes or regulations applicable to the work, and requirements of the local utility company concerned.

All materials used shall be listed by the *Underwriter's Laboratories, Inc.*, as conforming to its standard in every case where such standard has been established for the particular type of material in question.

Locating Relays.—The method of locating relays usually depends upon the size of the installation; that is, the number of relays required.

One method is to mount each relay through the outlet box at the fixture or outlet to be controlled. This may be called the *outlet mounted relay* method.

Another method is to group relays in gangs and mount them in centrally-located pull boxes. This may be called the *gang mounted relay* method. In large installations, such as shown in fig. 27, several of these pull boxes may be used.

The outlet mounted relay method shows greater economy, while the gang mounted relay method is easier to install and service, and provides an absolutely silent system.

A third method that is gaining in popularity and promises to become the standard method of installation is a compromise of the foregoing methods having the advantages of both. It may be called the *zone grouped relay* method. It consists of grouping several relays in a standard square outlet or small pull-box to take care of the relay requirements for a zone or small area.

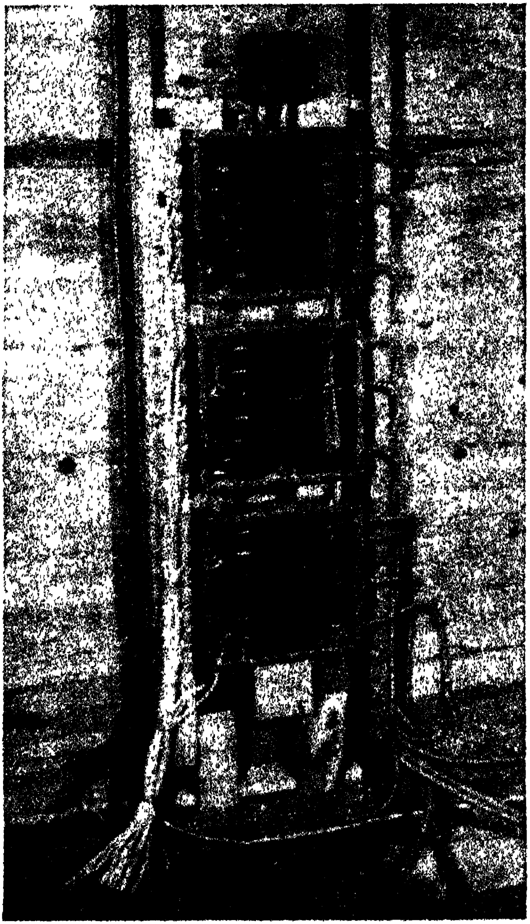


FIG. 27.—Showing typical pull box installation (with covers removed) located in attic of building or residence. This popular "gang-mounted relay" method provides for a division of voltages in a low-high voltage compartment, which not only facilitates circuit checking, but also gives the installation a neat and workmanlike appearance. This wiring method also affords flexibility, since additional pull boxes may be installed at any time without disturbing the existing circuits.

Outlet Boxes.—Before making any take-off, it is important to consider the following: For the *zone-grouped relay* method, select several controlled outlets from the wiring layout (usually not more than four) that are in the same area. Use this area or zone for the location of a standard square outlet or pull-box to mount the relays required. Break down the remainder of the wiring layout into smaller zones as conditions require.

Now fasten the square or pull-boxes in convenient locations in each zone so as to minimize the power line runs from the box to the outlets to be controlled. In ranch type houses the outlet or pull-boxes for ceiling or wall fixtures can be mounted in the attic. Obviously, each square or pull-box acts as a local distribution point for the associated outlets which must be on the same branch circuit.

For the *gang-mounted relay* method one pull-box will be sufficient in most residential installations. Where many outlets are required additional pull-boxes may be required. Many prefer to use two or three smaller boxes to reduce the power line runs.

A partition can be mounted in the pull box dividing it into a low and high voltage compartment with the relays mounted in the partition. Some prefer to mount a small pull-box inside a larger one and mount the relays with the low-voltage end inside the smaller box, while others prefer to mount the relays in the one-half-inch knock-outs in the side of the pull-box.

Relays Required.—In the take-off, one relay is required for each circuit consisting of one or more outlets that are controlled from the same switch or group of switches. For example, only one relay is required for several living room wall outlets all controlled from one or more switch locations. Where one switch or group of switches, controls outlets on more than one branch circuit, then one relay must be used for each branch circuit. Also where the total power requirements are in excess

of the relay rating, the outlets can be divided, using two or three relays to handle the divided load.

Mounting of Switches.—Switches can be mounted on boxes or box covers without the use of boxes by means of a special mounting strap furnished with the wall plate.

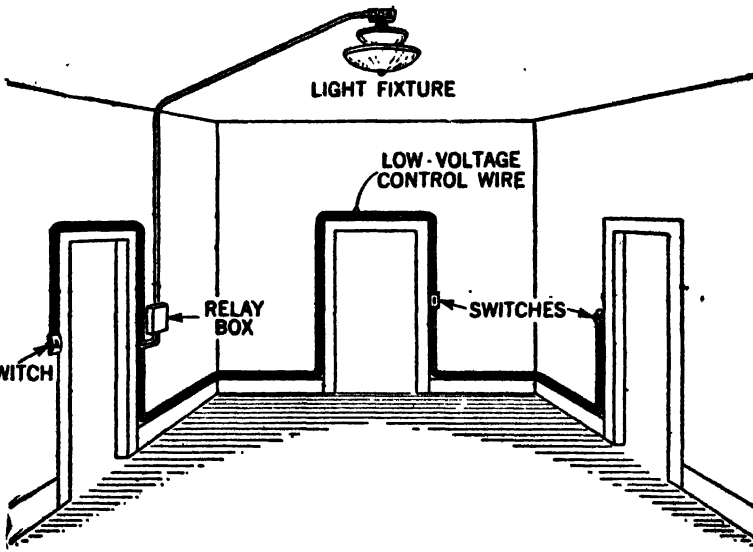


Fig. 28.—Showing method of remodeling existing wiring to furnish additional lamp control switches. Standard single gang switches can be replaced in this manner by one, two or three remote control switches and mounted to the sectional switch box by means of special mounting strap furnished with each remote control wall plate.

The master selector switch can be used in place of many individual switches that must be mounted at one location, or for master control of important lights and outlets from one or more points. The most usual location for this master and selector switch is the master bedroom. Many use a second

master switch at the entry point of a home to permit control of lights upon entering and leaving. The master selector switch can be wired so as to turn *on* one or more lights while turning *off* all others, simply by reversing the ribbed and unribbed conductors to those relays.

The rotary selector switch is designed to operate no more than nine relays independently. If more than one relay is connected to the same terminals of this rotary switch, then all the relays so connected will be locked together so that they all go *on* or *off* in unison. They cannot operate independently even though each relay may be wired to separate independent switches elsewhere. Pressing one independent switch will turn *on* or *off* all the relays so locked together. However, sometimes it is desirable to connect two or three relays to the same point on the master switch when two or more outlets on different branch circuits must be controlled in unison such as for stairwell lighting, or where more than one relay is used to handle a divided load.

Transformer Location.—When using the *gang-mounted relay* wiring method, it is best to locate the transformer close to one of the pull boxes. In the *outlet mounted relay* method the transformer is usually located in either the attic or basement in a central location.

Only one transformer is required for the average residence. For farms, commercial establishments, schools, hospitals and comparable installations, additional transformers are usually required.

Wire Identification.—Although it is possible to proceed with the installation without any prescribed procedure or system of wire identification, it is strongly recommended that a system

be established and carefully followed. To speed the installation, to reduce possible damage to installed equipment, and to minimize the chances of making the wrong connections which would result in incorrect operation of the relays or master selector switches, the procedure as outlined should be carefully followed in the order prescribed and the following proven wire identification system should be used:

1. The house plan should be split into zones.

2. Use two-conductor wire for all transformer runs.

3. Connect the ribbed conductors of all wires that go to the various zones to the same terminal on the transformer (this is very important when master selector switches are used).

4. Connect the ribbed conductors of transformer wires to the white leads, or terminal No. 1, on the relays. The unidentified conductors are spliced to the center conductors of the wires from individual remote-control switches.

5. Use three-conductor wire for all runs from individual switches to the relays they are to control.

6. Connect the ribbed conductors to the No. 2 binding screws of the switches, the center conductors to the center terminals of the switches, and the unribbed outside conductors to the No. 3 binding screws of the switches.

7. Connect the ribbed conductors to the red leads, or terminals No. 2 on the relays, connect the center conductors to the unribbed conductors of the transformer wires, and connect the unribbed outside conductors to the black leads, or terminals No. 3 on the relays.

8. Use two-conductor wire for all runs from master selector switches to relays. (Note: Only one relay can be individually controlled by each position of the master selector switch.)

9. Solder-ribbed conductors to left side lugs of master selector rotary switch. Solder unribbed conductors to right side lugs. Connect center of master selector switch to unribbed conductor of transformer wire and two connecting wires to rotary lugs as shown in diagrams.

10. Connect ribbed conductors of master selector switch wires to red leads, terminal No. 2. on the relays and the unribbed conductors to the black leads, terminal No. 3 on the relays.

Trouble Shooting

As soon as the wring is completed and the power switch is turned on the wiring system should be checked for proper performance. In checking the system, each circuit should be tested from each switch point including the master selector switch, to see that everything operates correctly. In case of faulty operation the following guide will be of value in locating and correcting the trouble:

1. ***Entire system dead.***

   a. Check current on transformer.

   b. Check to see if transformer is dead. If there is power on the primary leads (125 volt side) short out secondary terminals with screw driver. A spark will indicate that transformer is in working order.

   c. A short or open circuit in the transformer loop wiring may be found as follows:

      I. Disconnect the several zone circuits from the transformer secondary.

      II. Connect each zone to transformer separately and check relays in that zone.

      III. When zone is found in which the relays fail to operate, look for a short or open in the loop circuit. This can be done by disconnecting the transformer connections at the relay and testing the circuit at various locations for continuity, by the familiar "bell and battery set" or by a continuity tester of any type.

2. ***Individual Circuits Stay On or Off—Relay Hums and the Relay Barrel Becomes Warm.***—This fault is caused by a continuously energized relay coil.

   a. Check each control switch (including master selector switch; if the realy is controlled by the master) for a short between conductors at the terminals.

b. Check for a shorted control switch by disconnecting the wires from the terminals and shorting the one that was on terminal Number 2 to the one on center terminal, and the one that was on terminal Number 3 to the center conductor. If this operates the relay then the control switch should be checked. It may be necessary to allow the relay time to cool before making this test if the coil has been energized for an extended period of time.

3. ***Individual Circuits Stay On or Off—Relay Does Not Hum nor Become Warm.***—This fault is by an open circuit in the control wiring.

   a. Inspect the connections at the low voltage end of the relay to ascertain there are no open circuits.

   b. Inspect the connections at the control switches to see that they are not broken and are making good contact.

   c. If fault persists, check for continuity in the control wiring.

4. ***Circuit Turns On When Each Control Switch Is Turned Off.***

   a. Reverse connections to terminals Number 2 and Number 3 of the relay.

5. ***Circuit Turns On When Only One Switch Is Turned Off, but Is Correct from other Switches Controlling that Circuit.***—

   a. Reverse connections to terminals Number 2 and Number 3 of improperly operating switch.

TEST QUESTIONS

1. *What are the advantages of a remote control wiring system as compared to conventional control and wiring methods?*
2. *Why is a transformer necessary?*
3. *What is the voltage ratio of the transformer used in a remote control wiring system?*
4. *Describe the construction and function of the relay employed.*
5. *Why is the relay equipped with two coils?*
6. *What is the maximum voltage across the relay coils?*
7. *Describe the construction and operation of the control switch used.*
8. *Why are three terminals necessary on the control switch?*
9. *How is the multi-point control obtained in a remote control wiring system?*
10. *Describe the construction and operation of a master selector switch.*
11. *What is the maximum number of circuits which may be controlled from one master selector switch?*
12. *Describe the various applications for a remote control wiring system.*
13. *Describe the two common methods of locating relays in a remote control wiring system.*
14. *What is meant by the "gang mounted" relay location method?*

15. *What is meant by the "zone grouped" method of locating relays?*
16. *Describe the method used for location of outlet boxes in a remote control wiring system.*
17. *Why is only one transformer usually sufficient for each remote control wiring installation?*
18. *What are the methods employed to separate the 125 volt power supply from the 24 volts control source?*
19. *What are the ratings of the relay contacts?*
20. *What type of conductors are used for wiring* (a) *for the 24 volt control circuits and* (b) *for the 110 volt power circuit?*
21. *Does a wiring system of this class fulfill the requirements of the National Electrical Code?*
22. *What methods are employed when checking a remote control wiring installation for proper operation?*
23. *What is the maximum load that may safely be controlled from one relay in a wiring system of this kind?*
24. *If after completing a remote control wiring installation the lamp does not light properly, although the control switch is in working order, what procedure should be followed in order to find the trouble?*
25. *Draw a wiring diagram showing how three circuits may be controlled from a single-pole, double-throw control switch.*
26. *How many parallel connected relay coils may be operated from a single control switch?*

CHAPTER 115

Grounding

The term grounding as here used is defined as: *the intentional connection of a circuit to the earth for the purpose of insuring safety from shock.*

Thus, if any live conductor be efficiently connected to earth, a person touching the conductor cannot receive a shock, since there is no difference of pressure between the earth on which he is standing and the conductor which he is touching.

The principal reason for grounding a circuit is that of shock.

A person touching a circuit at any two points between which there is a difference of pressure, will receive a shock. The danger or severity of shock from touching simultaneously two live wires of a circuit is not affected by grounding the circuit, but the danger of severity of shock from touching simultaneously either wire and the ground does depend upon whether the circuit be grounded or not

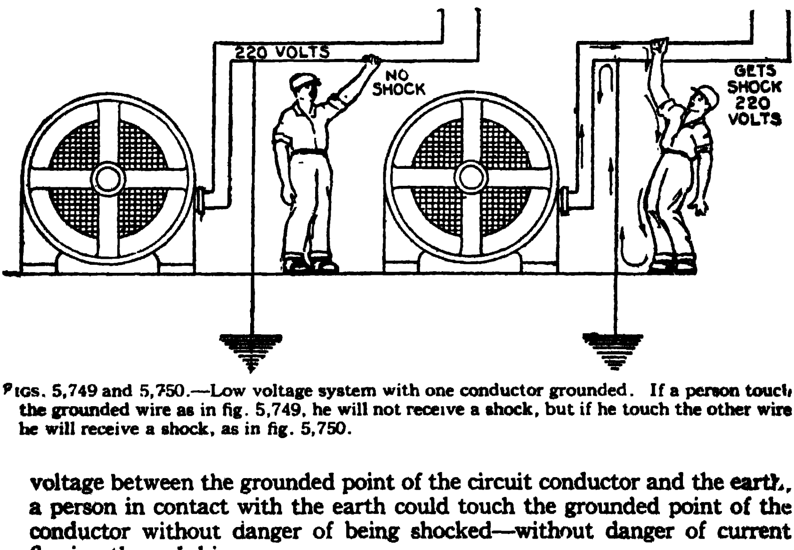
It should be noted that the sensitiveness of different people to shock varies a great deal and that the severity of a shock depends as much on the surface resistance of the skin (whether dry or wet) and on the parts and organs of the body through which the current passes, as on the voltage. It is therefore impossible to say that any voltage used in practice is so low that under no condition can it give a dangerous shock. However, considering ordinary conditions and the result of a majority of the shocks, circuits of voltages up to and including 220 volts may be considered as not liable to cause a serious shock, whether grounded or ungrounded, and may be referred to as *low voltage circuits*.

When a circuit is intentionallv grounded, the voltage of the

grounded point is made permanently that of the earth and the voltage of every other point of the circuit becomes fixed with respect to the ground.

When one conductor is grounded it depends upon which conductor a person touches as to whether he receives a shock, as in figs. 5,749 and 5,750.

The reason he receives no shock in fig. 5,749 is because the connecting of a point on the circuit conductor to the earth, insures that the point, on the conductor, and the earth will always be at (practically) the same voltage. It insures that there can be no voltage between them. Since there can be no



FIGS. 5,749 and 5,750.—Low voltage system with one conductor grounded. If a person touch the grounded wire as in fig. 5,749, he will not receive a shock, but if he touch the other wire he will receive a shock, as in fig. 5,750.

voltage between the grounded point of the circuit conductor and the earth, a person in contact with the earth could touch the grounded point of the conductor without danger of being shocked—without danger of current flowing through him.

Another way of looking at it is to consider that the ground wire, from the conductor to earth, forms a shunt around the person who is touching the conductor and that practically all of the current which flows to ground will flow through the ground wire and practically none through the person.

Danger arises in an ungrounded low voltage circuit when a high voltage wire comes in contact with one of the wires of the low voltage circuit, as in fig. 5,751.

This danger is avoided by grounding one wire of the low voltage curcuit as in fig. 5,752.

In grounding, two kinds of grounds are to be distinguished:

1. Grounding of conductor;

2. Grounding of conduit or other forms of containers for wires.

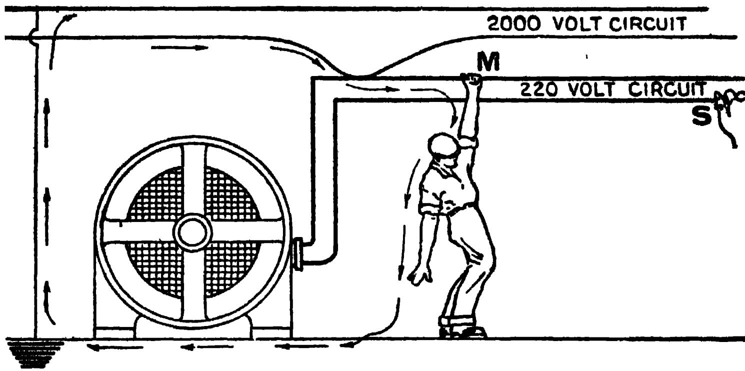


Fig. 5,751.—Ungrounded low voltage circuit in contact with a grounded high voltage circuit. A person gets a 2,000 volt shock if he touch wire M, and a 2,220 volt shock if he touch wire S.

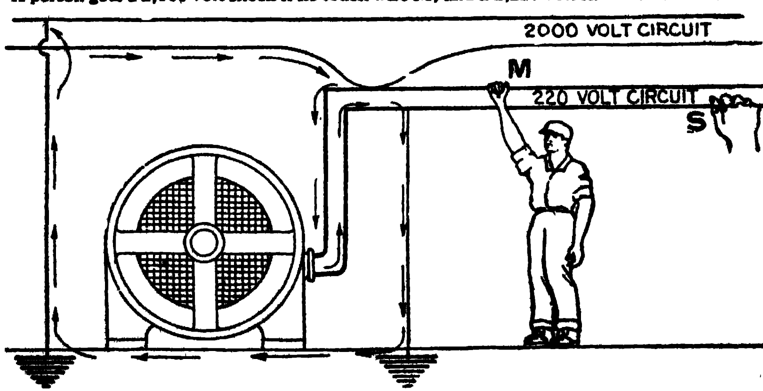


Fig. 5,752.—Grounded low voltage circuit in contact with a grounded high voltage circuit. A person gets a small shock if he touch wire M, and no shock if he touch wire S.

The reason why a conduit should be grounded is because in case of a short between the conduit and one of its wires, and the external circuit come in contact with a wire on a grounded high tension circuit a person touching the conduit would be subject to the high voltage, as indicated in fig. 5,753.

Ground Wire.—This wire is used to connect a circuit conductor, conduit, or other device to an earth plate, water pipe, etc. The ground wire used must not be smaller than No. 10 copper.

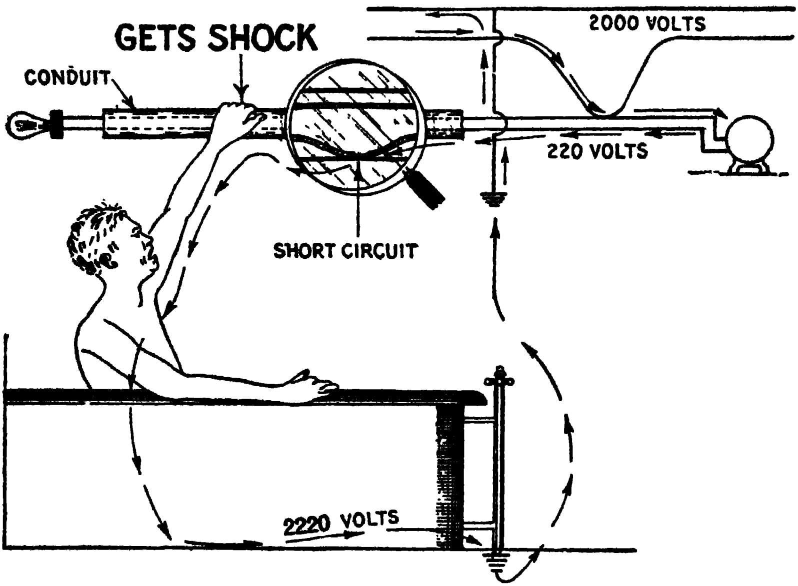


FIG. 5,753.—Diagram illustrating the importance of grounding conduit or external metal covering on lighting circuits.

Larger sizes of wire may be used, and are required for large service installations. The size of wire required for grounding is determined by the ampere capacity of the service wires. This ground wire need not have any insulation, and may be fastened to the building with nails or staples or with cleats or knobs.

One end of the ground should be sweated to a lug and the lug should be bolted to the service switch cabinet. All service switch cabinets are arranged

for grounding. The other end should be sweated to a ground clamp. The wire should be run as straight as possible to a water pipe and be fastened to the latter on the street side of the meter. If the distance to a pipe on the street side of the meter be considerable, and a cold water pipe on the house side of the meter be available, the ground wire may be attached to the latter and a copper jumper should then be placed around the meter.

When the neutral wire is grounded, No. 8 copper wire, rubber covered, single braid, must be used, and it should be encased in conduit from the service switch to the ground clamp.

Ground Connection.—Generally a water pipe is selected for a ground connection in house wiring installations. In the absence of which, efficient connection can be made as by means of embedded plates or pipes driven in the ground.

Driven pipes possess many advantages over other methods which have been used, such as buried plates, buried strips, coils of wire, and the various patented ground electrodes commonly advertised.

Chief among the advantages are the low cost of the pipes as compared with the other forms of ground electrodes, and the simplicity of driving a pipe compared with the task of excavating for and installing the buried form of ground electrode. Moreover, the ground area required by a driven pipe is small, a decided advantage in some places where excavation is out of the question because of restricted space or pavements.

Another noteworthy advantage is that the connection between the ground wire and the driven pipe can be made above the surface of the ground, which affords easy inspection and testing, and eliminates the possibility of a defect being obscure, such as a ground wire broken below the ground surface by corrosion or by mechanical thrusts and shifting caused by frost.

An analysis of the electrical resistance to earth formed by the different types of grounds shows that the driven pipe compares very favorably with any of its competitors. It has, also, the outstanding advantage that two or more pipes may be driven and connected in parallel at a cost usually less than that of one of the buried types of grounds, and thus it is possible to obtain a very much lower ground resistance with driven pipes than with the other types for a given cost.

Where permanent moisture is at a considerable depth in the soil, the

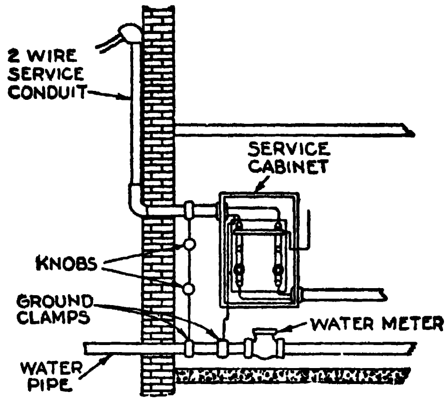
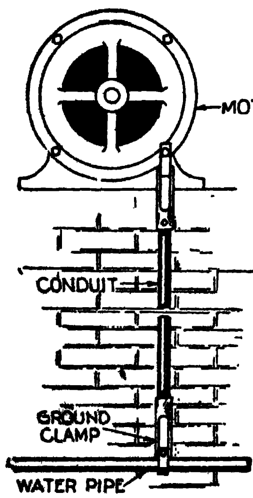


FIG. 5,754.—Method of grounding neutral and service cabinet. Some cities permit grounding to cold water pipes without *jumping* the water meter. Whether or not meters should be jumped depends upon their construction.



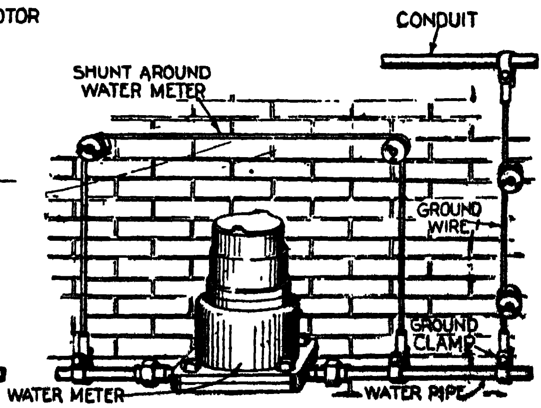


FIG. 5,755.—Method of grounding a motor frame.

FIG. 5,756.—Method of grounding conduit system to water pipe.

driven pipe has an obvious advantage, being capable of reaching depths of twenty feet or more where the soil is of friable texture.

Copper clad steel ground rods have been used in a few cases and in general have the same characteristics as pipe.

They have the additional advantage of resisting corrosion over a somewhat longer period, and they also allow a simple soldered connection to the copper ground wire. Their cost, however, is considerably more than even the extra heavy galvanized pipe for a given diameter.

Apparently there has not been enough experience with the copper clad steel rods in actual service to say definitely whether their extra expense is justified by added life. Considered on the same cost basis as the standard iron pipes, the copper clad rods would be entitled to favor.

NOTE.—*An efficient earth plate* can be made of copper sheet No. 16 gauge, some 2 square m in area, to which the earth connection of, say, No. 0 gauge is soldered across its whole width, and may also, with advantage, be riveted. The plate should be placed in a hole in the ground with some 60 cm. depth of coke or charcoal, crushed to pieces the size of a pea, below it, and with the same amount of coke or charcoal above it. The hole must be of sufficient depth to reach to permanently damp earth, and is filled in after the plate and coke have been placed in position. If no suitable permanently damp earth can be reached, it may be necessary to run a water pipe to the plate in order to keep the surrounding ground moist.

TEST QUESTIONS

1. *Define the term grounding.*
2. *What is the principal reason for grounding a circuit?*
3. *When a conductor is grounded what is the condition for receiving a shock?*
4. *Name two kinds of grounds.*
5. *Why should a conduit be grounded?*
6. *What is a ground wire used for?*
7. *What size of ground wire should be used?*
8. *How should a ground wire be connected?*

9. *What is usually selected for making a ground connection?*
10. *Do driven pipes possess many advantages over other methods for ground?*
11. *What is the chief advantage of a pipe ground?*
12. *Is a large ground area required for a driven pipe?*
13. *Give method of grounding a motor.*
14. *Do copper clad steel ground rods make good ground?*

CHAPTER 116

Overhead Systems

There are various kinds of transmission lines in which the wires are suspended overhead on poles, towers or other methods of support. They are known as overhead systems and may be classed

1. With respect to the voltage, as

   a. Low voltage.
   b. Medium voltage.
   c. High voltage (high tension).

2. With respect to length of line, as

   a. Short lines.
   b. Lines of moderate length.
   c. Long distance.

3. With respect to service, as

   a. Telephone.
   b. Telegraph.
   c. Light.
   d. Power,
   etc.

4. With respect to the current, as

a. Direct current {two wire, three wire}

b. Alternating current {single phase, two phase, three phase}

5. With respect to the method of support, as

a. Pole line.

b. Transmission tower.

c. Catenary.

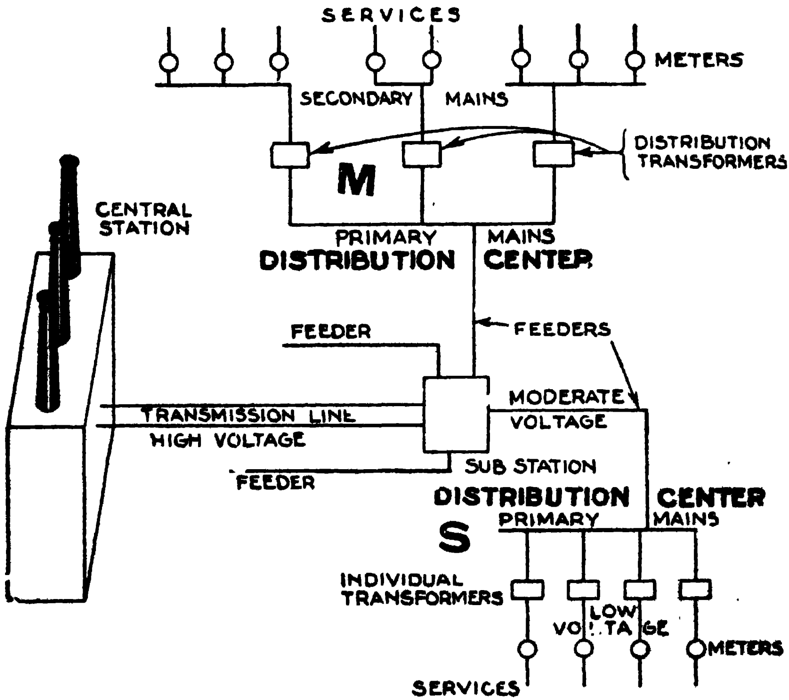


FIG. 5,795 —Diagram of a typical overhead transmission and distribution system.

6. With respect to the circuit, as

   a. Metallic.
   b. Ground return.

A typical overhead system for light and power consists of

1. Transmission line;
2. Feeders;
3. Primary mains;
4. Secondary mains.

Fig. 5,795 shows the elements of such a system.

Starting at the central station, the alternators of moderate voltage produce the current. This voltage is for lines of moderate or long distance stepped up by transformers in the central station in amount depending upon the length of the transmission line.

The voltages ordinarily used for transmission lines are as given in the following table:

Transmission Line Voltages

Length of Line	Voltages
1 to 3 miles	550 or 2,200 volts
3 " 5 "	2,200 " 6,600 "
5 " 10 "	6,600 " 13,200 "
10 " 15 "	13,200 " 22,000 "
15 " 20 "	22,000 " 33,000 "
20 " 30 "	33,000 " 44,000 "
30 " 50 "	44,000 " 66,000 "
50 " 75 "	66,000 " 88,000 "
75 " 100 "	88,000 " 110,000 "
100 " 150 "	110,000 " 132,000 "
150 " 250 "	132,000 " 154,000 "
250 " 350 "	154,000 " 220,000 "

The amount and cost of power to be transmitted is an important factor in determining the economic transmission voltage.

For average conditions isolated from existing transmission lines the voltages shown in the table have been quite generally used. For exceptional cases, exceptional values will be used.

Example: If 40,000 *kva*. be transmitted 20 miles, 66,000 volts or higher might be used. On the other hand, if a very small amount of power be transmitted, lower voltages would probably be selected.

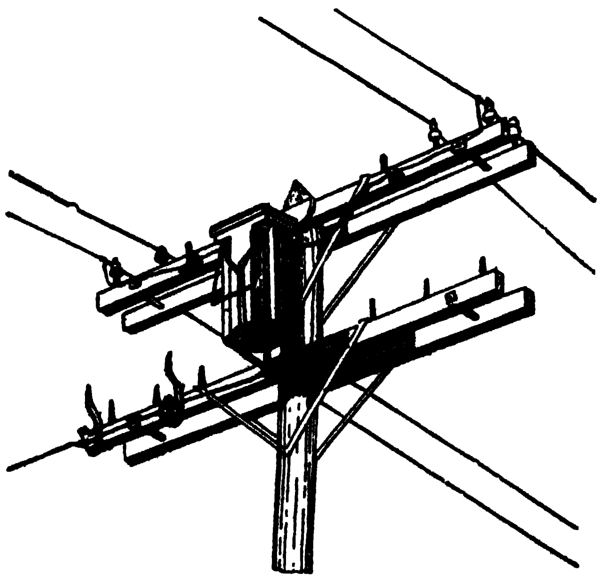


FIG. 5,796.—One 2,300 volt transformer on line.

At the sub-station the current coming in over the trans mission line at high voltage is "stepped down" by transformers

*NOTE.—The use of 187,000 volts is likely to occur only in case it be found necessary to have a voltage between 154,000 and 220,000 volts.

to a pressure suitable for the feeders. According to H. B. Gear, a rule of thumb allowance is *about* 1,000 *volts per mile length of transmission.**

This gives a conductor too small for short lines transmitting considerable power. Accordingly for short lines, a somewhat higher voltage should be selected.

The feeders lead from the sub-station to the distribution centers, each distribution center having a separate feeder and no branch circuit should be tapped to the feeders between the sub-station and the distribution center.

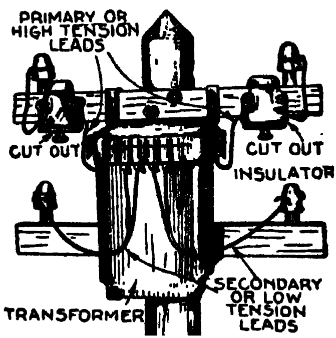


FIG. 5,797.—Installation of a transformer on pole; view showing method of attachment and disposition of the primary and secondary leads, cut outs, etc.

The object of this is to prevent undue drop along the feeders. The voltage at the distribution center should be maintained constant for all loads and this is usually accomplished by means of feeder voltage regulators located at the sub-station and fully described in Chapter 79.

Each feeder, terminating at a distribution center, is connected to the primary mains.

*NOTE.—*The above rule* is based on the fact that with copper conductors a pressure of 1,000 volts per mile, and a current density of 1 amp. per 1,000 *cir. mils*, the energy loss will be about 10 per cent.

Along the primary mains, conductors are tapped at various points. In fig. 5,795, the feeder **M**, is tapped at several points, each line connecting with a distribution transformer which reduces the pressure for the secondary mains. Each distribution transformer serves several customers as shown. A slightly different scheme is used for distribution center **S**. Here individual transformers are used for each service. The distributors and individual transformers step down the voltage from usually 2,300 volts to 115 or 230 volts.

The foregoing general description of a simple overhead systen is intended to illustrate transmission and distribution principles. Of course in practice an infinite variety of hook-ups can be used to meet the varied conditions to be met with. The object in view, in the selection of any particular system, is to transmit the current from the central station to the customer in the most efficient manner and with the least expense.

TEST QUESTIONS

1. *Give classification of overhead systems.*
2. *Draw a diagram of a typical overhead transmission and distribution system.*
3. *Give transmission line voltages for lines ranging from 1 mile to 350 miles.*
4. *What are the functions of a sub-station?*
5. *What is a rule of thumb allowance for voltage per mile of transmission line?*

CHAPTER 117

Pole Line Materials

For lines of low and moderate voltage, poles are used to support the conductors. To meet the varied conditions several types of poles are used. They may be classed, with respect to materials, as

1. Wooden;
2. Steel;
3. Concrete.

Wooden poles are the ones mostly used.

In tropical countries, however, such as India, Central America, etc., where wood is rapidly destroyed by the ravages of white ants and other insects, steel poles are almost exclusively used for telegraph, telephone, and other electric transmission lines.

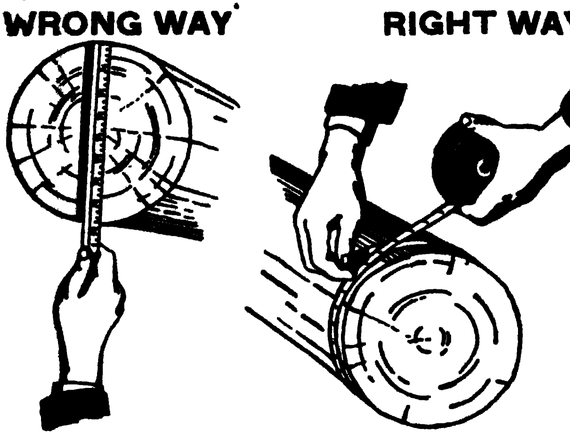
Wooden Poles.—The properties required in these poles are strength, comparative lightness in weight, durability, straightness, a gradual and well defined taper and an abundant and accessible supply.

These requisite properties, especially that of durability, restrict the number of species which can be used for poles, and about 80 per cent of the poles used in the United States are cut from two classes of timber. These two classes are chestnut and cedar, and of the two approximately five times as much cedar as chestnut is used.

According to wire capacity, poles are divided into several classes, as

Class A.—Poles to be used in lines carrying or ultimately to carry forty wires.

Class B.—Poles to be used in lines carrying or ultimately to carry from twenty-one to forty wires.



FIGS. 5,798 and 5,799.—Right and wrong way to measure tops or butts. The terms 5 in. top, 20 ft.; 7 in. top, 30 ft. are used to designate the size of poles, but the diameter measurement is not a correct means of determining the size of a top, because the tops are not exact circles. Instead, the size of a top or butt is determined by the circumference measurement on all poles 16 ft. and longer.

Class C.—Poles to be used in lines carrying or ultimately to carry from thirteen to twenty wires.

Class D.—Poles to be used in lines carrying or ultimately to carry from seven to twelve wires.

Class E.—Poles to be used in lines carrying or ultimately to carry from three to six wires.

Class F & G.—Poles to be used in lines of two wires, the wires being carried on brackets.

The following table gives standard specifications for Western red cedar "class" poles according to N. E. L. A. and American Tel. & Tel. Co.

Minimum Dimensions of Pole—Circumference in Inches

Length of Pole in Feet	CLASS A Top	CLASS A 6-ft from Butt	CLASS B Top	CLASS B 6-ft. from Butt	CLASS C Top	CLASS C 6-ft. from Butt	CLASS D Top	CLASS E Top	CLASS F Top	CLASS G Top
20	24	33	22	29	18¾	27	18½	15½	15½	12½
22	24	34	22	30	18¾	28½	18½	15½	15½	12½
25	24	36	22	32	18¾	30	18¾	[illegible]	15½	12½
30	24	40	22	36	18¾	33	18¾	18¾	18¾	
35	24	43	22	38	18¾	36	18¾	18¾	18¾	
40	24	47	22	43	18¾	40	18¾	18¾	18¾	
45	24	50	22	47	18¾	43	22	22	18¾	
50	24	53	22	50	18¾	46	22	22	18¾	
55	24	56	22	53	18¾	49	22	22	18¾	
60	24	59	22	56					18¾	

Pole Preparation.—In the production of poles it is necessary that they pass through various stages of preparation, such as:

1. Cutting;
2. Peeling;
3. Seasoning.

Poles should be cut in winter, because at this time of the year wood destroying insects and fungi are least active and drying is slow, which is advantageous.

The object of peeling is to facilitate drying or seasoning, and when the poles are to be treated with preservative, it is absolutely necessary in order to secure penetration of the liquid. The poles should be peeled immediately after cutting.

When a tree is cut, it immediately begins to lose water.

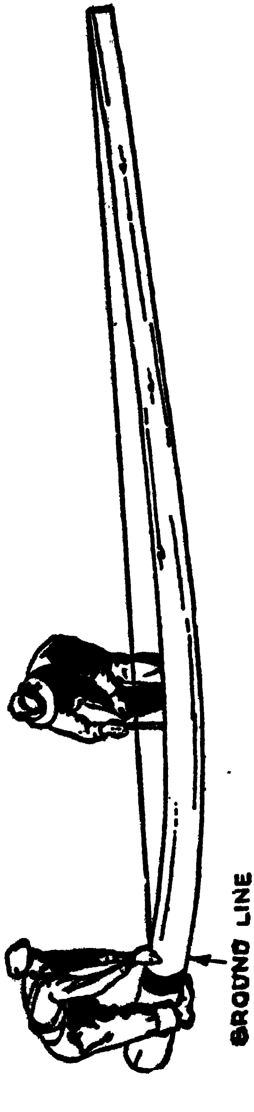


Fig. 5,800.—Method of measuring sweep. *To measure* the amount of sweep in a pole, a tape is stretched tight from the top to a point six ft. from the butt end. A rule can then be used to determine the amount of sweep at the greatest distance between the pole and tape.

This loss of water is termed *seasoning*, and is accompanied by other changes in the wood, such as oxidation of the wood substances and fixation of inorganic and organic compounds.

As moisture is an essential factor in the development of fungous growth, the proper drying of a pole prevents injury from decay. The strength of a pole is increased by seasoning, and as the weight of the pole is decreased, the shipping charges on it are reduced.

During the seasoning process water leaves the cell cavities and if continued sufficiently, the cell walls.

Other changes occurring are the splitting or checking of the cell walls and the rupturing of the bordered pits.

All these changes increase the air spaces in the wood and facilitate the entrance of preservative liquids.

The most common method of seasoning poles is to pile them in the open air.

Wood Preservation.—There are several processes which may be successfully employed for the preservation of poles or other exposed timber. The best known of these are the

creosoting, burnettizing, kyanizing, carbolizing, and vulcanizing processes.

The method of treatment employed by some large pole concerns is as follows: The butt ends of the poles are first immersed to the proper depth in heated creosote, ranging in temperature from 212° to 230° F. These temperatures while allowing a suitable range above the boiling point of water, keep to a minimum the amount of volatilization of the lighter toxic constituents of the preservative which would otherwise be lost in the atmosphere. The heat of the preservative being conducted into the timber, expands the air within the cells and vaporizes moisture or sap which might be present.

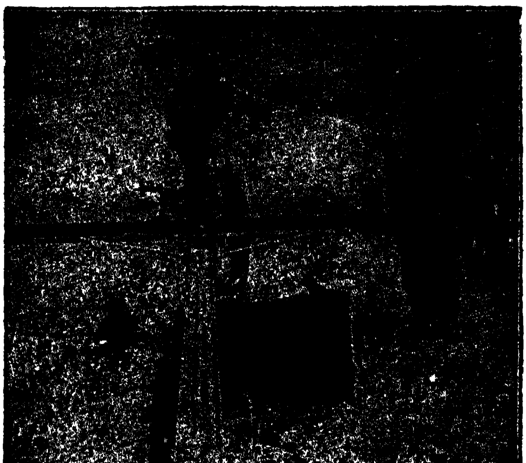


FIG. 5,801.—*Erecting Bates steel pole 1.* Attaching an angle iron cross arm.

In the heat treatment, the vapor formed by the expanding of the air within the cells is forced from the timber and escapes. After the timber is heated for a minimum of four hours, the hot preservative is withdrawn and cold preservative introduced into the tanks. This change of temperature causes a contraction of the expanded air in the cells of the wood, which in turn forms a vacuum. drawing the surrounding preservative well into the timber

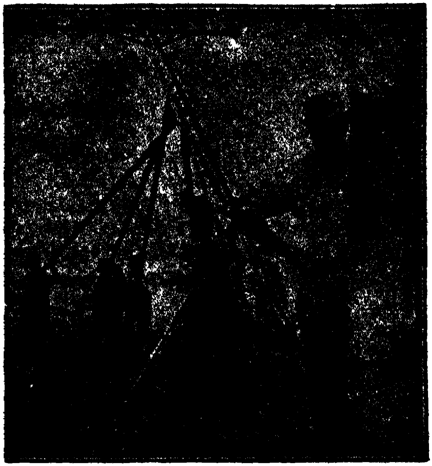


FIG. 5,802.—*Erecting Bates steel pole 2.* Raising the pole by the use of pike poles.

FIG. 5,803.—*Erecting Bates steel pole 3.* A one piece single pole held plumb by temporary stays while the concrete foundation is constructed.

FIG. 5,804.—*Erecting Bates steel pole 4.* Pole as erected showing foundation, also a method of climbing by means of Bates pole climbers.

Steel Poles.—On account of the increasing cost of wood and the relatively short life of wooden poles, steel poles are extensively used. The various types may be classed as:

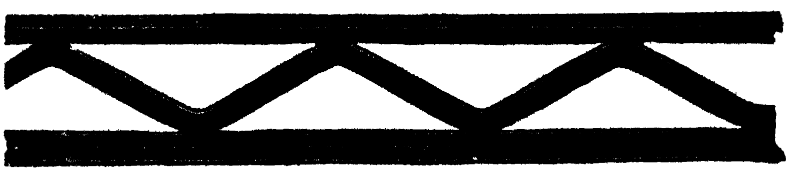
1. Tubular;
2. Structural;
3. Expanded.

Tubular poles consist of sections of steel pipe of varying diameter with the largest diameter at the butt. One end is expanded wider than the other and is used as the base of the pole.

Latticed steel poles are made by a large number of manufacturers, this being a type of construction in universal use. The design and adaptation are so diversified that no detail can be given.

When using this type of pole, as in using other types of pole, it is a matter of calculating the loads which are to be placed upon the structure, necessary clearances and factors of safety, and from this the structure itself can be chosen from standard types or designed by any competent structural engineer.

The expanded type is made from an I-beam by cutting and



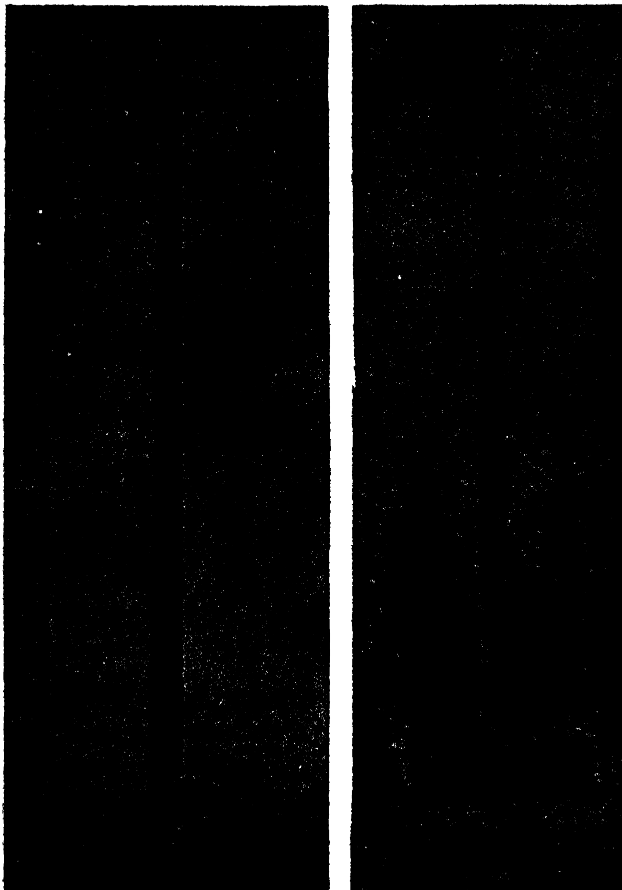
FIGS. 5,805 and 5,806.—Method of making Bates expanded steel truss pole. The pole is manufactured from rolled "H" sections designed for poles. The section is first sheared through the web by a rotary shear, leaving intact portions at fixed intervals throughout the length of the section, as in fig. 5,805. The section is then heated to a cherry red color, and is then charged into an expanding machine, which automatically grips the flanges throughout their entire length and expands the section to the desired dimension while hot. Expanding the sheared web causes the middle portion of the web to take the zigzag form, as in fig. 5,806, and thus creates a series of triangles in alignment and produces a strong, one piece steel truss.

expanding the web, making what is termed an "expanded steel truss pole."

Figs. 5,805 and 5,806 illustrate the manufacture of this type pole.

Concrete Poles.—These poles are very durable and will outlast any wooden poles. While wood has been most widely used, on account of its low first cost, concrete possesses advantages which are being given increasing attention where

long life, greater strength and increasing safety factors must be considered.



Figs. 5,807 and 5,808.—Westinghouse hollow concrete poles in telephone service. These poles are suitable for telegraph, trolley and transmission.

Among these advantages is the fact that a carefully worked out design can be commercially produced with unvarying certainty, thus insuring a fixed safety factor. Furthermore, the growing scarcity of timber is leading progressive companies to install experimental lines of concrete poles, so that they may have an opportunity to study this type of construction first hand before economic factors force them to adopt concrete for all their lines.

So far as is known, reinforced concrete poles are not subject to the ordinary action of the elements. Water tends to harden concrete and does not affect the reinforcing steel, since it is entirely embedded and therefore inaccessible to it and the air.

There are two general types of concrete poles:

1. Solid;
2. Hollow.

The solid type is made in a trough form and is reinforced by steel rods running lengthwise.

In the manufacture of hollow concrete poles, the reinforcing steel, after being accurately computed for the particular class of pole to be made, is held rigidly in the place it was designed to occupy, so that the actual tests of strength check the design very closely. The complete reinforcing cage is then placed in a horizontal form and held at the desired distance from the surface of the form by concrete buttons which become part of the finished wall of the pole. Concrete is added and the entire form rotated at high speed developing centrifugal force sufficient to compact the concrete into a very dense wall, leaving a hollow opening in the center running through the length of the pole.

Cross Arms.—The familiar cross arms for stringing wires are usually attached to the poles before they are erected. They are commonly made from yellow pine wood, generally 3¼×4¼ inches, and are freely coated with good mineral paint as a preservative.

Attachment is made to the pole by cutting a *gain* one inch deep and of sufficient breadth to allow the longest side of the cross arm to fit accurately. It is then secured in place by a lag screw with a square head, so that it may be driven into place with a wrench.

The cross arm is further secured to the poles with braces. Fig. 5,809 shows a typical arm and fig. 5,810 the method of fastening to pole.

Pins and Insulators.—The cross arms are bored with holes

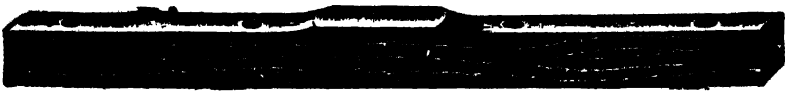


FIG. 5,809.—Cross arm which carries the insulator pins. The standard cross arm is $3\frac{1}{4} \times 4\frac{1}{4}$ ins., double painted, and bored for $1\frac{1}{2}$ in. pins and two $\frac{1}{2}$ in. bolt holes. Telephone arms are $2\frac{3}{4} \times 3\frac{3}{4}$ ins., bored for $1\frac{1}{4}$ in. pins and two $\frac{1}{2}$ in. bolts.

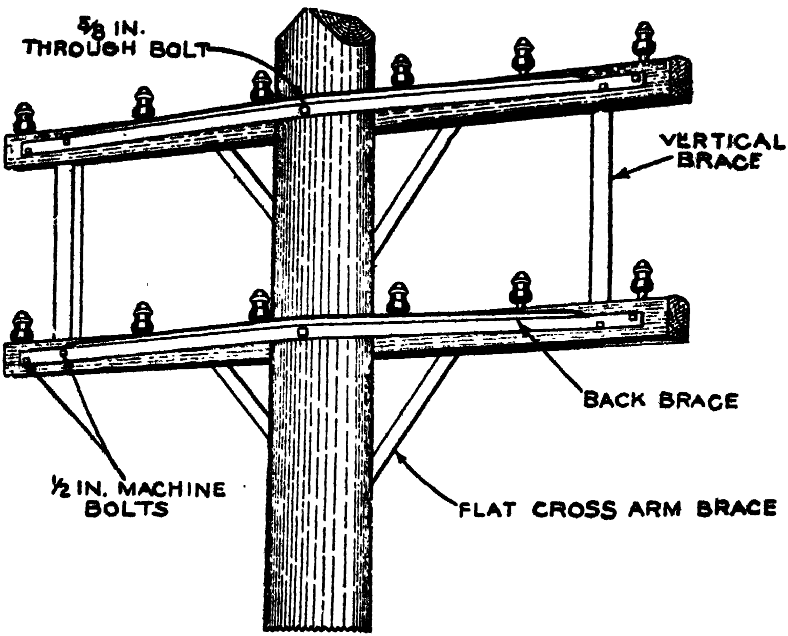


FIG. 5,810.—Method of fastening cross arm to pole. *In addition* to direct bolting, the c arm is further secured to the pole with braces 30 ins. long, $\frac{1}{4}$ in. thick and $1\frac{1}{4}$ in. wide, according to standard specifications. Holes are bored at points one in. from either end, one for attaching to the pole, the other for attaching to the cross arm; two braces forming a triangle with the cross arm for the base and with the apex at the point of connection to the pole.

for the insertion of the insulator pins, which are made of locust wood and threaded at the upper end to receive the glass insulators.

The cross arm is made of such a length as to accommodate the number of pins to be inserted. An arm for two pins is made three feet long, according to the standard usually followed, with holes for the pins at center points three inches from either end and a space of 28 inches between them in the center.

Figs. 5,811 to 5,813 show a glass insulator, pin and bracket such as is used on telephone and telegraph lines.

Figs. 5,811 to 5,813.—Glass insulator and insulator pin and bracket. The insulator here shown is of the pony double petticoat type. Insulator pins are used with cross arms, brackets are attached direct to the pole.

Insulators.—Glass and porcelain are employed almost universally for supporting overhead wires. Insulators made of these materials are superior to those made of other material such as hard rubber, or various compounds of vegetable or mineral matter, with the exception perhaps of mica insulators used on the feeders or electric railway lines.

Glass insulators are generally used on low tension lines, and porcelain insulators on high tension lines, the latter type being usually stronger and less brittle. Porcelain is more expensive than glass, and its opacity prevents the detection of internal defects which would be readily observed through glass.

An insulator which has one, two or three deep flanges or "petticoats" around the base for the purpose of increasing the leakage path from the line to the pin is called a petticoat insulator.

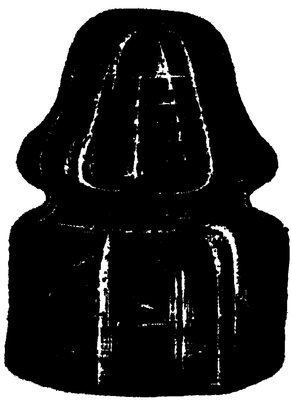
Both glass and porcelain insulators may be the double or triple petticoat

type which may be cast or moulded solid, or made in two or more parts which are subsequently cemented together.

Figs. 5,814 and 5,815 show these types of insulator.

There are numerous types of insulators adapted in design to the various conditions met with.

Guys for Poles.—Where poles are subject to severe strains which might throw them down and break the wires, guy cables are largely employed, these being attached near the top and



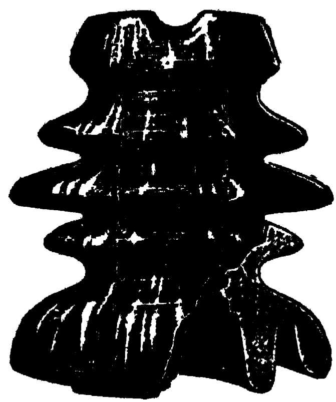


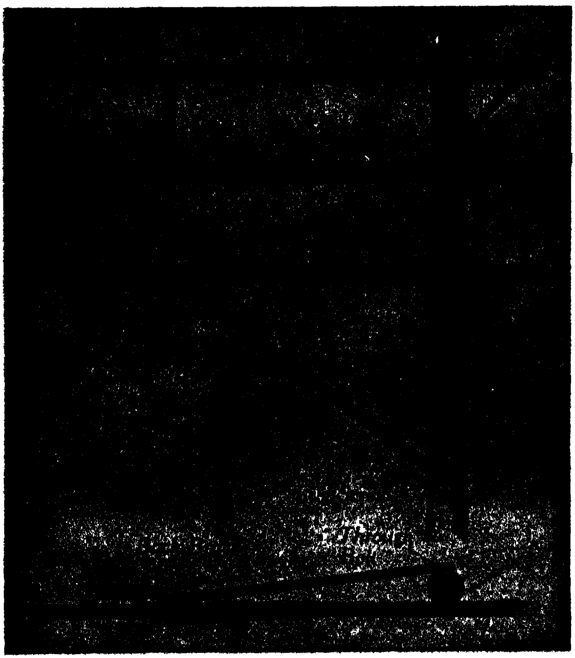
FIG. 5,814.—Telephone and telegraph line glass insulator.
FIG. 5,815.—Type of insulator used in making a transposition.

secured either to the base of the next pole, to a suitable guy stub or post, or to a guy anchor, which is buried about eight feet in the earth and held down by stones and concrete.

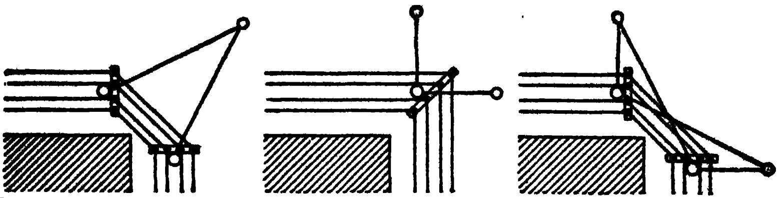
Poles should be guyed at corners in order to thoroughly secure the poles so that no strain may come on the cornerwise span. It is also necessary to guy a line where it is to be deflected from a straight path, as when rounding a hill, water course or railway curve, in order to neutralize the pull of the wires, tending to incline the poles toward the center on which the arc is described; also when descending a hill.

The methods of guying poles are shown in the accompanying cuts.

Guy Stubs and Anchor Logs.—In guying a line under such conditions, each pole is connected by a suitable cable to a guy post or "stub," or to an anchor log.



FIGS. 5,816 and 5,817.—Hubbard tee pole braces. The vertical brace shown is designed for 3 arms spaced 12 ins. apart, or 2 arms on 24 in. centers, additional arms being cared for by placing other vertical braces in *series* with the first. The vertical brace is made of $1\frac{5}{8} \times 1\frac{5}{8} \times \frac{1}{4}$ in. angle and is provided with poles for $\frac{1}{2}$ in. bolts. The diagonal brace is intended for use on both the 6 and 10 pin arms. It is provided with a step for the line man and may be used on either side of the pole. It is fastened to the side of the pole by a $\frac{1}{2}$ in. lag screw, and to the cross arm by a $\frac{1}{2}$ in. machine bolt. The diagonal brace is made of $2 \times 2 \times \frac{3}{16}$ in. angle steel. The back braces are attached to the pole by the $\frac{5}{8}$ in. cross arm through bolt and to the cross arm by a $\frac{1}{2}$ in. machine bolt. Back braces are made of $2 \times 2 \times \frac{1}{8}$ in. angle steel.



FIGS. 5,818 to 5,820.—Methods of guying corner poles. The proper guying of corner and terminal poles is especially important; on corners and curves, the guys should be stronger and more frequent and should be placed at the outer side as shown in the diagrams.

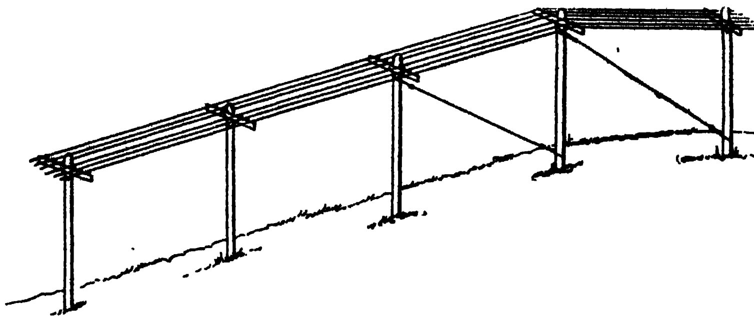


FIG. 5,821.—Head and foot guying of a pole line in descending a hill.

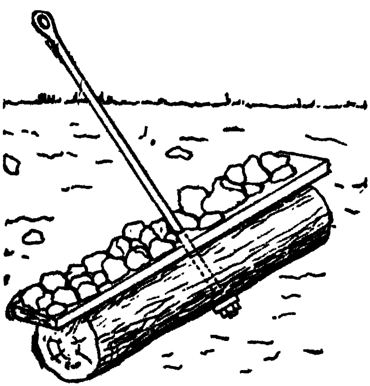


FIG. 5,822.—Guy anchor log in position.

Standard rules specify stubs between 18 and 25 feet, with exact limits as to circumference measurements at the top and at a point 6 feet from the butt, according to the kind of wood used. Figs. 5,822 and 5,823 show two types of anchor.

FIG. 5,823.—Stombaugh guy anchor. It is made of cast iron and can be screwed into the ground like an auger.

TEST QUESTIONS

1. *What range of voltage is employed on pole lines?*
2. *Name three classes of poles.*
3. *What kind of pole is mostly used?*
4. *What are the properties required in wooden poles?*
5. *How are wooden poles classed according to wire capacity?*
6. *Draw a sketch showing right and wrong way to measure pole butts.*
7. *How is the sweep of a pole measured?*
8. *Name the several methods of wood preservation.*
9. *Describe the preservation method employed by some large pole concerns.*
10. *Describe pole climbers.*
11. *Describe the method of erecting steel poles.*
12. *How is an expanded steel truss pole made?*
13. *Describe another type of steel pole largely used.*
14. *What may be said with respect to concrete poles?*
15. *What are the advantages of concrete poles?*
16. *Name the two general types of concrete poles?*
17. *Give the construction of the solid type of concrete pole.*
18. *How is a hollow concrete pole made?*
19. *What are cross arms?*
20. *How are the wires attached to the cross arms?*
21. *What materials are used for insulators?*
22. *What provision is made where poles are exposed to severe strains?*
23. *Describe the various methods of guying poles.*

CHAPTER 118

Erecting Pole Lines

Before starting an erecting job, ascertain whether or not all necessary permits have been secured in order that the work may be done in accordance with the detail plans.

If any part of the proposed work requiring a permit be not covered by a permit, do not begin operations until everything is covered by permits.

Ordering Poles.—Car load lots should be specified. A schedule should be attached to the order covering the shipment to be made, delivery points, and the required date at each delivery point.

Pole storage yards should be provided at delivery points, and the poles should be hauled from these yards to the stake, either by the company's forces or a teaming contractor, depending on which is more economical.

Where poles are obtained locally it is desirable to have them delivered at the stake by the supplier and orders for poles should so specify, if conditions permit.

The person making deliveries should be furnished with a location or stake list showing the length and class of pole to be delivered at each stake, and the date when delivery is required.

The delivery of poles in piles along a route should be avoided where practicable.

Unloading Poles from Cars.—In many cases poles may be unloaded to advantage by local contract. There are several methods of unloading poles as

1. By cutting the stakes;
2. By dragging off car end;

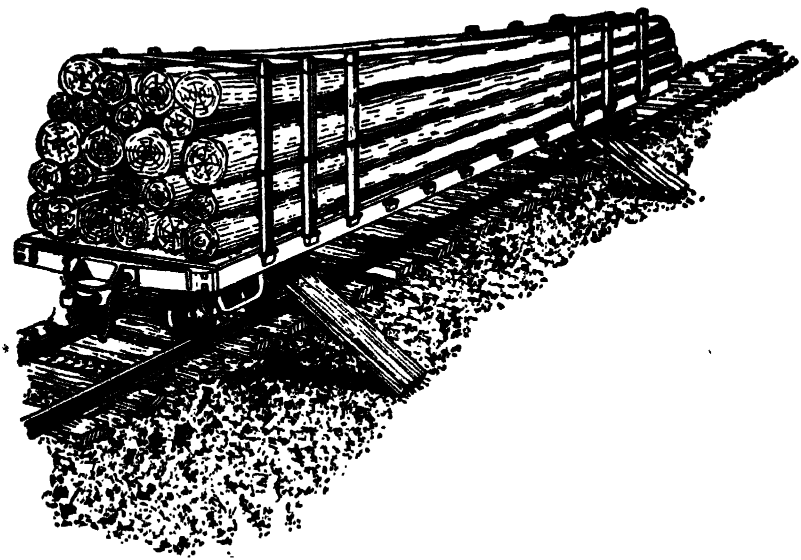


FIG. 5,824.—Unloading poles. *1st Method.* First cut stakes on one side of car, then cut tie wires on other side, allowing poles to roll off. This is a dangerous method. For safety see that the stakes have amply strong tie wires at top and at center of stakes. Where any doubt exists regarding their strength pass a one inch rope or 6,000 lb., or larger, strand over the load at each end of the car, and secure it so that the load is bound in place.

3. By means of pole derrick;
4. By lowering with rope.

These methods are shown in figs 5,824 to 5,827.

Storing of Poles.—Where poles are to remain in the yard for a considerable period of time, they should be sorted according to different classes and lengths and placed on skids. Make the skids of old poles where practicable and space them about fifteen feet apart in a location where water does not accumulate.

The end poles of the pile should be prevented rolling by means of blocks spiked to the skids or stakes driven into the ground. Where piles are more than one pole high, each layer should be carefully "nested" on the layers beneath. Butts of poles should be reversed on alternate layers when the pile will be four or more layers high.

Locating Poles and Stubs.—In general, measure off the span

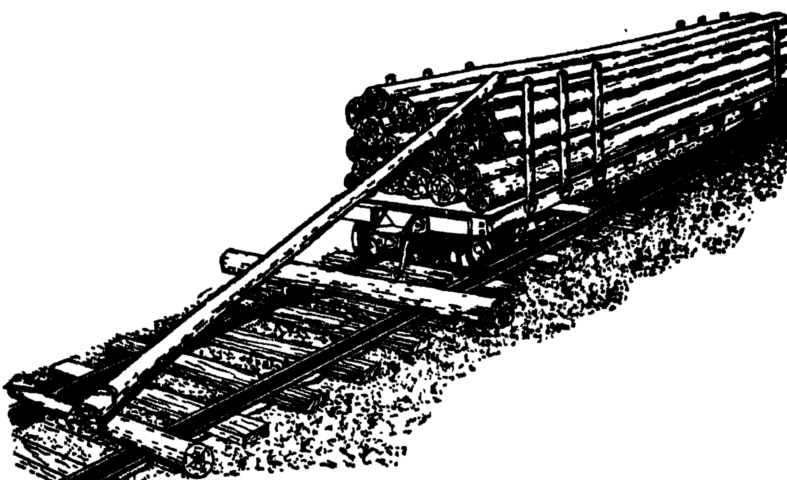


FIG. 5,825.—Unloading poles. *2nd Method.* Dragging poles off the end of the car. Lay temporary skids across the tracks at the end of the car, as shown. Attach pole tongs, rope sling or chain to end of pole and pull pole off the end of car so that it lands on the skids. Where this procedure would be liable to break the pole, the end of the pole which is last to leave the load should be lowered to the ground. Pole tongs attached to a rope may be used for this purpose; take a turn around the top of a stake with the rope where necessary, to prevent the pole descending too fast. Roll the poles clear of the tracks.

lengths specified for the line until an obstacle or a fixed pole location, such as a corner, dead end, or crossing is reached.

Locate a pole at a satisfactory distance from the obstacle or at the fixed location. If it be then found that the span adjacent to this pole be 10% over or 20% under the specified length of span, relocate a sufficient number of the adjoining poles so as to make all spans come within the desired locations.

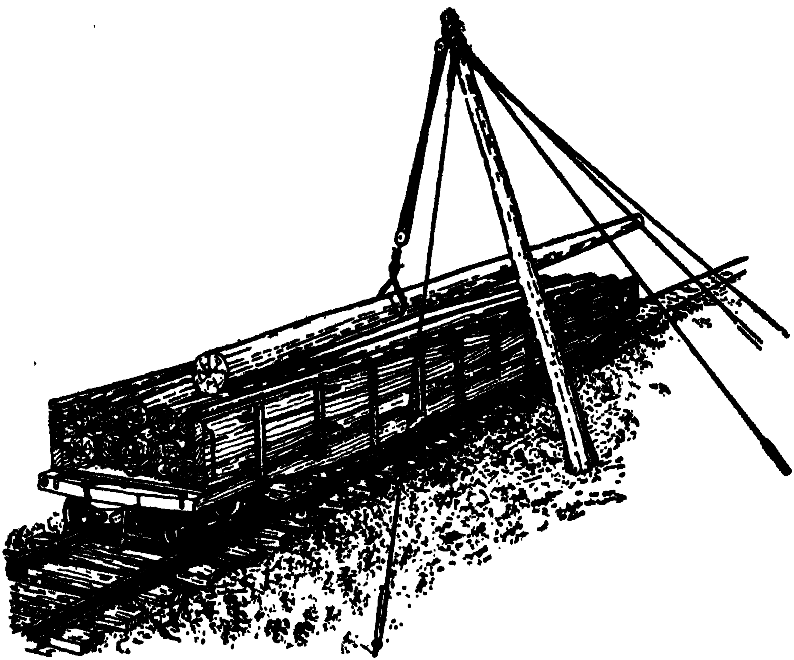


FIG. 5,826.—Unloading poles. *3rd Method.* Use a pole derrick or gin pole.

Drive stakes at the proposed pole and stub locations.

Where the line requires poles of different heights for grading, the pole height required should be marked on the corresponding pole location stake.

The number of poles specified per mile should, in general, not be increased or decreased by more than one pole, except where long span construction occurs. Locate poles in line, except corner poles.

Locate terminal poles so as to obtain good guying facilities and so that if there be an underground connection, the conditions will be favorable for building the subsidiary conduit and pulling in the cable.

Along the highway, except in municipalities, locate line close to the highway fence line, but avoid, so far as practicable, having cross arms overhang private property. When conditions permit, locate poles at transverse fence or property lines.

Where local regulations provide a definite location for pole

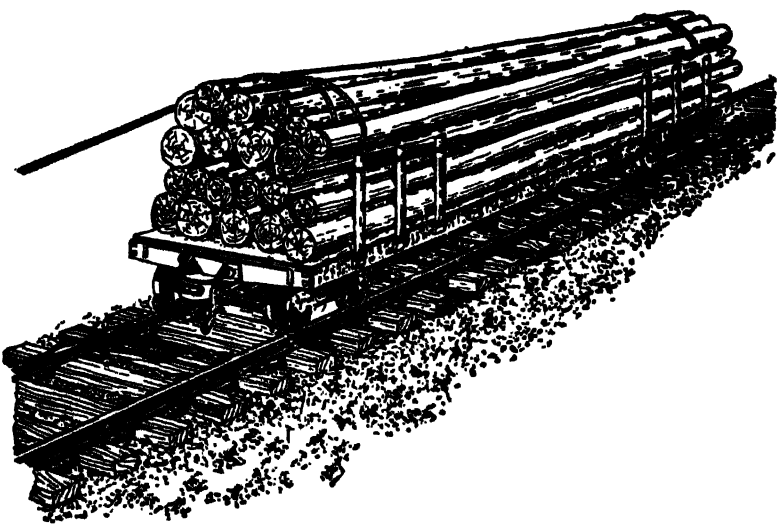


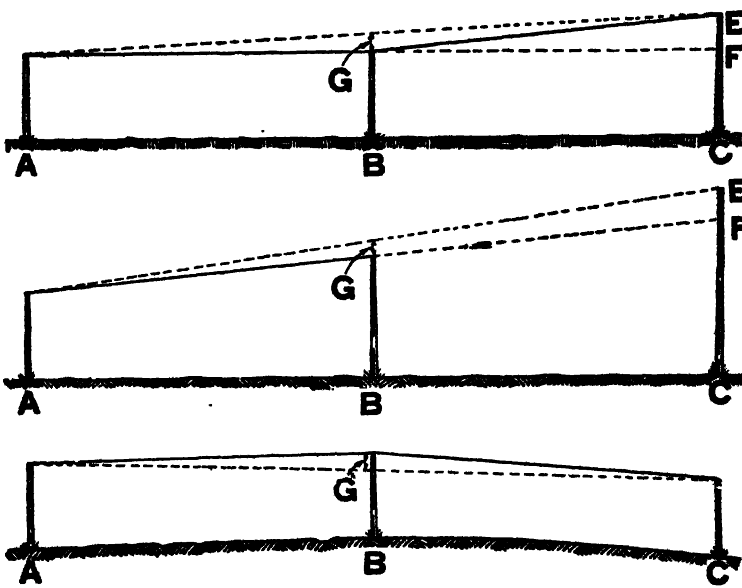
FIG. 5,827.—Unloading poles. *4th Method.* Lowering poles to ground by ropes. At each end of the car secure the end of a rope to the top of a sound stake on the side of the car opposite the unloading side. Pass these ropes over the load and under the first pole to be unloaded. Then bring them back to the opposite side of the car, take a turn around the top of the stakes and pass the ends to a man whose duty it is to tend them. Cut the tops off the stakes on the unloading side at a point just below the top layer of poles. Ease off on the ropes, thus allowing the first pole to roll over the edge of the load. Pay out the rope slowly until the pole touches the ground. Roll the pole clear of the rope and repeat the operation with the poles on top layer, rolling them to the edge of the load with cant hooks or peavies. Similarly unload the remaining layers, cutting stakes at proper level for each layer.

lines, for example, at a fixed distance from the center of the highway, the regulations must be complied with.

Poles on highways outside of incorporated limits should be placed between the drainage ditch and fence line or highway limits. Do not set poles between drainage ditch and highway without special approval of county or state authorities.

Avoid long curves, a line should consist of straight sections and corners. Avoid locating poles in inaccessible places, such as marshes, steep banks, etc.

Avoid the use of long or short poles for grading the line by shifting the stake locations (but not more than 10% over or 20% under the specified



FIGS. 5,828 to 5,830.—Change of grade diagrams. *By definition* a "change of grade" is *a change in the slope of a line which results in an up pull or a down pull at a pole*, as shown in the diagrams At up pulls G, the change of grade on pole B, is approximately equal to one-half the distance EF. The point F, is located by sighting across the tops of poles (or rods) A and B. At down pulls G, the change of grade on pole B, may be found directly by sighting across the tops of poles (or rods) A and C.

span length) so as to keep poles off the summits of mounds and the bottoms of depressions.

Avoid pole locations which will involve the wires in tree branches or foliage where pruning rights will be difficult to obtain. Locate exchange poles so as to facilitate joint use.

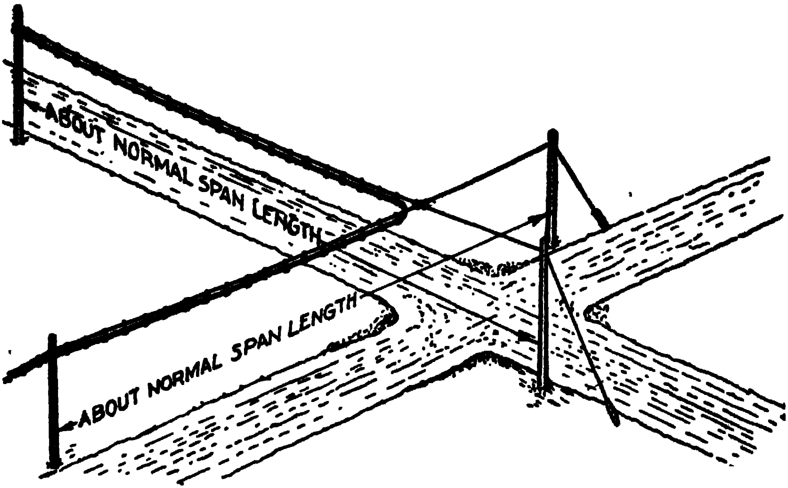


FIG. 5,831.—Main aerial cable turn at street corners. Use a single pole corner if guying conditions permit. At street corners, where conditions such as radius curbs, sewer inlets, etc., will not permit a single pole corner, and at other locations where it is not practicable to make a single pole corner, make the corner as here shown.

Pole Location at Corners.—Locate corner poles so as to obtain good guying facilities. Corner poles should be "set in" to give the proper rake, where conditions are favorable and appearances permit, as shown in fig. 5,861.

In open wire lines use a single pole corner where the pull is less than 40 feet. Where the pull on a single pole would be 40 feet or greater, in general make the corner on two poles. Where a two pole corner is impracticable, a single pole corner with special cross arm construction may be used.

Grading the Line.—A line should follow the general contour of the ground over which it passes, avoiding, however, any

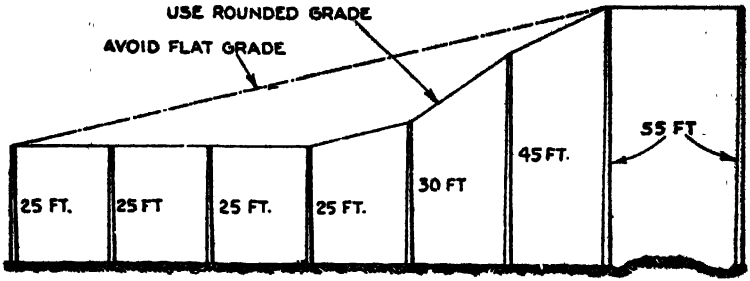


FIG. 5,832.—Rounded and flat grades. A rounded grade is one which has a change of grade on practically every pole, whereas a flat grade has a change of grade on the first and last poles only of a slope. It will be noted that the rounded grade requires fewer high poles than the flat grade.

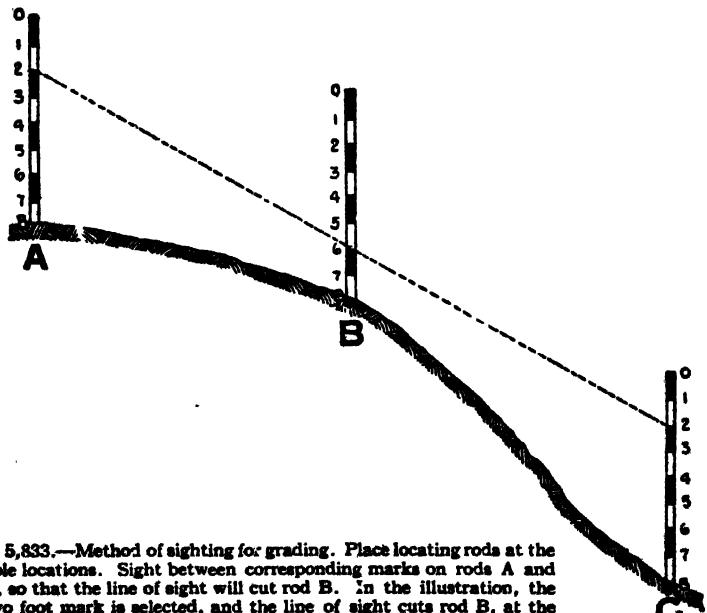


FIG. 5,833.—Method of sighting for grading. Place locating rods at the pole locations. Sight between corresponding marks on rods A and C, so that the line of sight will cut rod B. In the illustration, the two foot mark is selected, and the line of sight cuts rod B, at the six foot mark. This indicates that there is a change of grade of four ft. (6 ft.—2 ft.) on stake B. If it be desired to have the pole tops in line, pole B, should be four feet shorter than poles A and C. If the change in grade be found to be in excess of the allowable limits, it would then be necessary to select a pole of such length as would bring the change of grade within the allowable limits.

abrupt dips or rises which would cause excessive pull on tie wires, pins, or other attachments on the pole. In all cases, poles should be made as short as the required clearances and allowable change of grade on each pole will permit.

Where it is necessary to increase or decrease the height of attachments on poles in order to obtain required clearances, the change should be made by using *rounded* grades, rather than *flat* grades, as shown in fig. 5,832. The method of sighting for grading is shown in fig. 5,833.

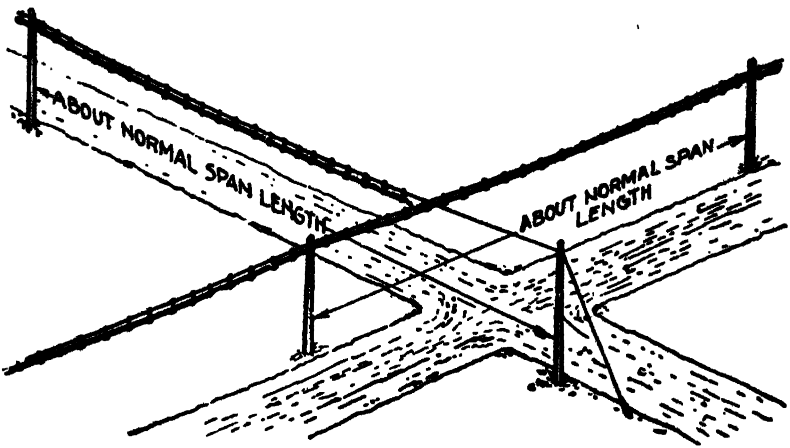


FIG. 5,834.—Branch aerial cable turn at street corners.

Framing Poles.—This work should be performed before setting. Where practical it should be done in the pole yard. If done on the job, the work should be so arranged as not to interfere with the men setting poles. Where framing is done in the yard or on streets, remove the chips at the end of each day's work.

Creosoted poles are delivered with the gains and other framing already cut. In no case should the creosoted surface of the pole be penetrated.

Framing poles consists of several operations:

1. Trimming;
2. Shaving;
3. Roofing;
4. Gaining;
5. Boring.

FIGS. 5,835 and 5,836.—*Roofing.* Turn the pole so that the face (or inside of the sweep) is up and hold the pole in that position either by blocking or by placing the top of the pole in a gaining buck. Mark the angle of the roof (90°) and cut it with a saw, taking care not to splinter the wood at the bottom of the cut.

Trimming.—Trim off all knots, and cut off all projecting parts of the butt which would interfere with the pole entering a full sized hole. Do not decrease any dimension which would reduce the life of the pole. Trimming includes stripping off all the bark; it is necessary in order to reveal defects in the pole, prevent decay and make the pole safer for the lineman.

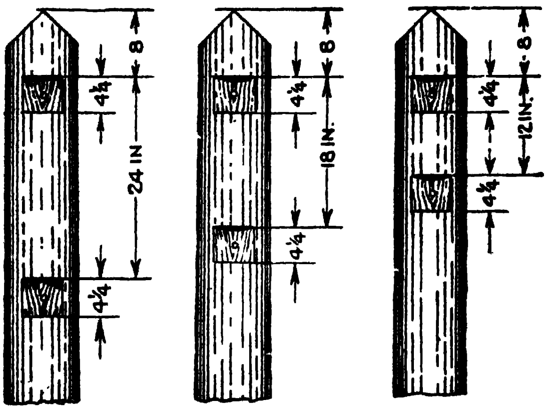
Shaving.—This operation is performed with a draw knife but should be done only when required. Shave only the section of pole or stub which is to extend above the ground or is to be treated.

Roofing.—This operation consists in forming a roof in the top of the pole. This is done by sawing the two sides of the pole top at the angle shown in figs. 5,835 and 5,836. Note that the ridge is at right angles to the gains.

Gaining.—By definition a gain is *the notch cut into the pole into which the cross arm is placed when mounted.* Gains are cut to provide a flat surface to help maintain the arms in alignment.

Cutting a gain consists in first sawing along the upper and lower edges of the gain with a hand saw, and then chiseling out the round portion and making a flat recess.

It is good practice to hollow out the gains slightly in the center to insure a snug fit of the cross arm, thereby preventing its rocking from side to side The operation is shown in detail in figs. 5,837 to 5,839.



FIGS. 5,837 to 5,839.—*Gaining.* Locate gains on the inside of the *sweep* on curved poles. Measure distances accurately and cut gain so that a tight fit is obtained when cross arms are placed. *In general,* space gains 24 ins. apart, top to top of gain. With approval of supervisor, this distance may be reduced to 18 or 12 ins. to obtain proper clearance. Where phantom transposition brackets are to be placed, the cross arm spacing must not be less than 24 ins. Where A or B transposition brackets are to be placed, the cross arm spacing must not be less than 18 ins. On jointly used poles cut gain for telephone cross arm so that the clearance between this cross arm and the nearest cross arm or attachment of the electric company, will comply with the local regulations.

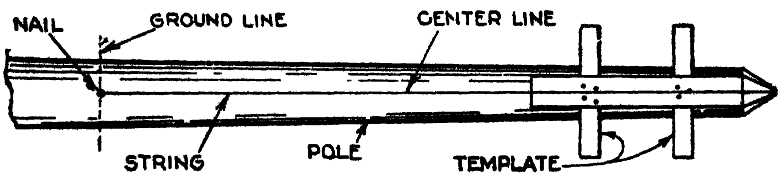


FIG. 5,840.—Gain template and method of aligning on pole. If the arms of the template be made of flexible material such as sheet metal, they may be bent to conform with the pole surface, thus permitting the gain lines to be scribed with precision.

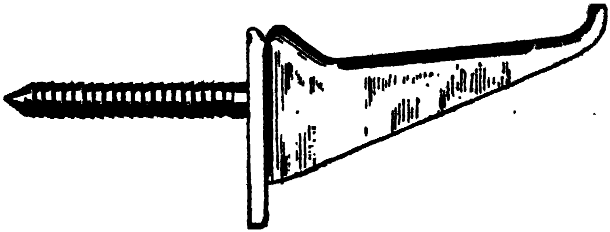


FIG. 5,841.—Hubbard "Pierce" detachable pole step.

FIG. 5,842.—Installing Pierce detachable step. *Step 1.* Slip the plate over the lag and drive the lag screw until the plate bites into the pole.

FIG. 5,843.—Installing Pierce detachable step. *Step 2.* The step slips down in a groove on each side of the lag screw head.

FIG. 5,844.—Installing Pierce detachable step. *Step 3.* The lineman attaches the steps as he climbs the pole.

FIG. 5,845.—Removing Pierce detachable step. *Step 4.* After the lineman is finished working on the pole, he removes the steps and carries them away.

Where the line is to carry only cable or distribution wires attached to brackets, no gains are necessary unless the municipality requires one.

Boring.—A hole should be bored for a $\frac{5}{8}$ in. cross arm bolt in the center of each gain. The hole should be so bored that when the cross arm is drawn up tight, the bolt will be at right angles to the face of the cross-arm. Where practicable, holes for cable suspension clamp bolts and pole steps should be bored before the pole is erected. The last operation completes the work of framing.

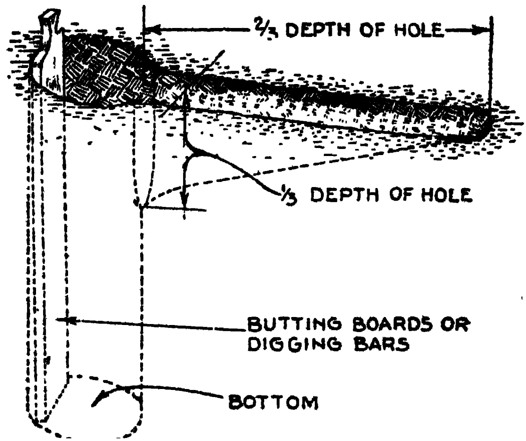


FIG. 5,846.—Digging a hole for a large pole. Where a large pole is to be erected with pikes, or any pole is to be raised with a bull rope, dig a trench extending from the hole, in line with the direction from which the pole is to be raised.

Stepping the Poles.—Poles which require frequent climbing should be provided with steps to prevent damage to the pole from the climbing spurs of the workman. The steps should be spaced 18 ins. apart and located alternately on opposite sides of the pole.

The lowest step is placed not less than $6\frac{1}{2}$ ft. from the ground. A form of detachable pole step is shown in fig. 5,841.

Digging Pole Holes.—When stakes are used to show pole

locations, dig hole around the stage as a center. Where no stakes are used, holes should be dug where directed.

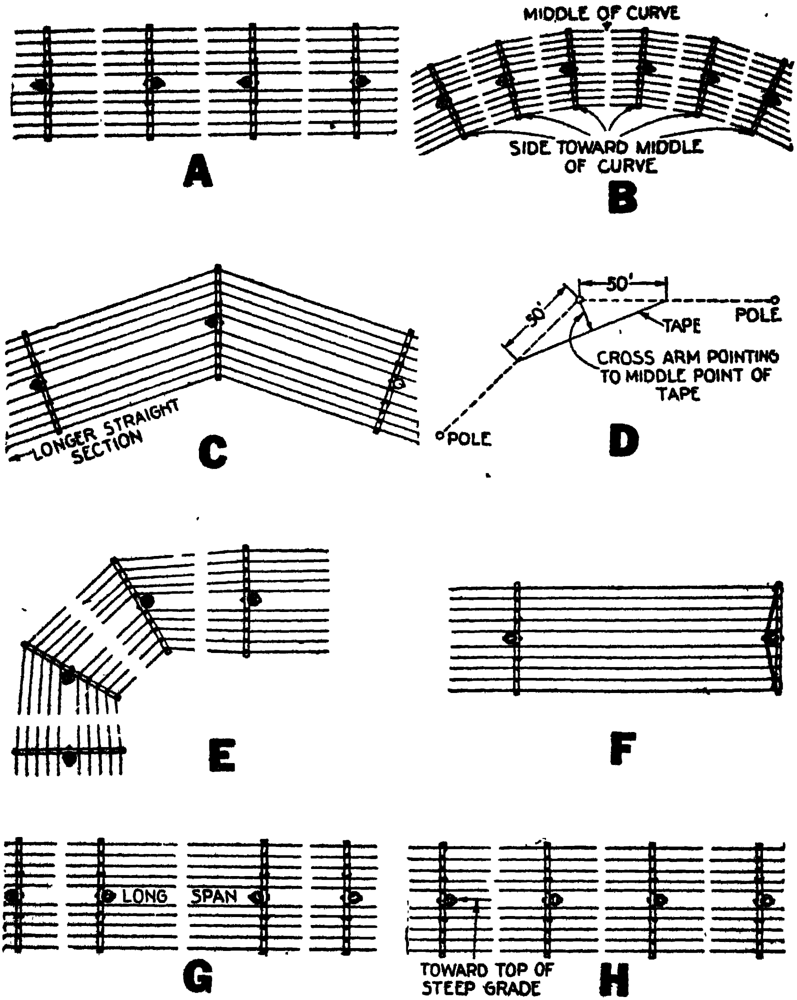
The holes must be dug large enough to permit the free entrance of the pole without cutting down its normal circumference at the butt, and of sufficient size to permit tamping throughout their entire depth. The sides of the holes must be straight.

The following table gives the depth of holes for various poles set in level ground except that unguyed stubs and corner poles must be set deeper by 6 ins. or more, according to the nature of the soil.

Depth of Holes for Poles

POLE LENGTH IN FEET	SETTING IN EARTH DEPTH IN FEET	SETTING IN ROCK DEPTH IN FEET
20	4	3
22	4	3
25	5	3
30	5½	3½
35	6	4
40	6	4
45	6½	4½
50	7	4½
55	7½	5
60	8	5
65	8½	6
70	9	6
75	9½	6
80	10	7
85	10½	7
90	11	7

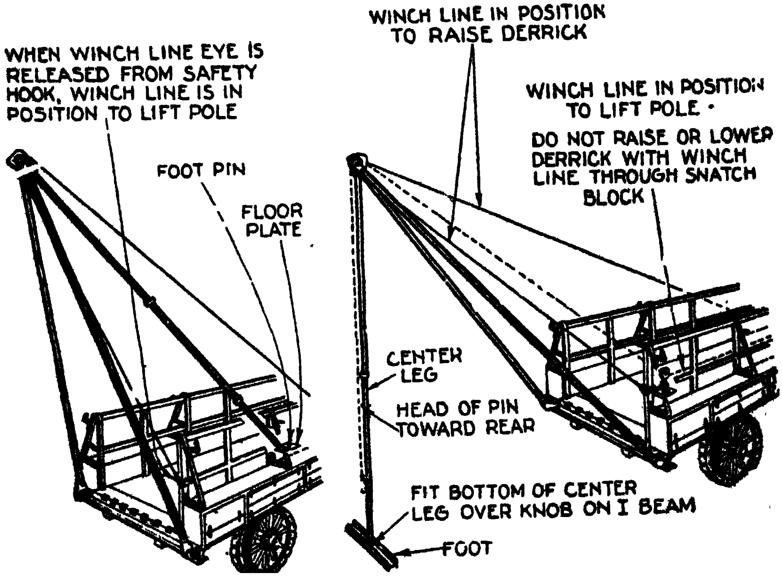
NOTE.—*Dig just enough holes each day* to permit the pole erecting gang to do a full day's work. Where holes remain open at the end of the day's work, cover them well or guard them to prevent accidents. Where conditions require it, the holes should be covered with substantial planking immediately after they have been dug.



FIGS. 5,847 to 5,854.—How to face cross arms. **A**, on straight section; **B**, on curve; **C**, at corner; **D**, two pole corner; **E**. at dead ends. toward end of line on last 2 poles; **F**, at long spans, away from long span; **G**, at steep grades, toward top of grade; **H**, on grade.

In ordinary soil use a hole boring machine, or shovel, digging spoon and digging bars.

In soft soil, which caves while digging, use a barrel with the heads removed, or a split iron cylinder to act as shoring. The barrel may be left in place after the pole is erected. Where the earth is soft and the load on the pole will be heavy, dig the hole large enough so that a foundation of rock, concrete or plank may be placed at the bottom of the hole to keep the pole from sinking.



Figs. 5,855 and 5,856.—*Erecting poles, 1st Method.*

Facing Poles.—By definition the face of a pole is *the side of the pole on which the cross arms are attached.*

Set the poles so that ridge of pole roof is in line with lead. Ridge of junction pole roof should be in line with main lead. Ridge of stub roof should be in line with guy. The proper facing of the cross arms is shown in figs. 5,847 to 5,854

Erecting Poles.—In general, the method to be employed in

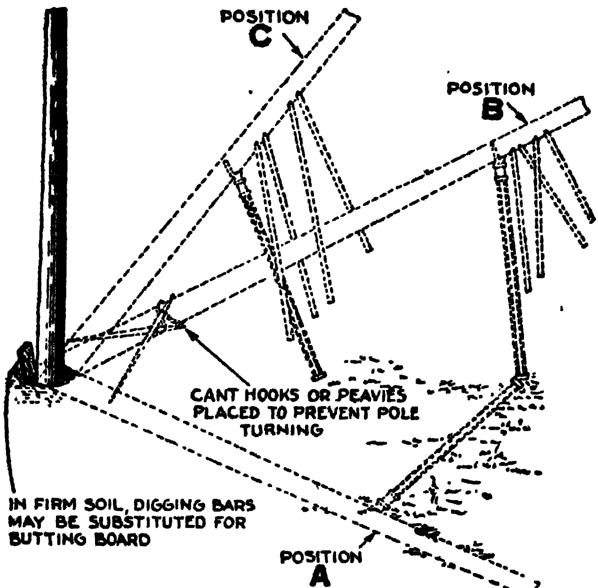


FIG. 5,857.—***Erecting poles, 2nd Method.*** Place butting board (used in soft soil) or digging bars (used in firm soil) in the hole. Move pole into place with butt against butting board. Place deadman or jenny in position along the ground where footing will be secure, and station a man to attend it. Position *A*. Lift pole and deadman to position *B*. If pole be brought into place on a dinkey, lift top of pole and place deadman underneath. Place 2 cant hooks or peavies, one to pull against the other so as to serve as a means to prevent the pole turning as it is being raised. The cant hooks or peavies should be placed about 2 feet above probable ground line. When a pole is treated, the hooks must not penetrate the treated wood. Station a man to hold the hooks as the pole is being raised. Place pike poles near the top of pole, one on each side, to steady the pole as it rises and the others underneath the pole. At this stage, the side pikes should be held with the two hands separated and the lift pikes should be held in the hollow formed by clasped hands. Raise the pole, then move the deadman down until it supports the pole again. Position C. In changing the location of the deadman, keep it in instant readiness to support the entire weight of the pole. Pole may be lifted from position B, to position C, by hand, if more convenient. Apply pikes further down the pole. Position C. Shift the pikes one at a time. Raise the pole again. When the pole passes the 45° angle, the men on lift pikes may work to better advantage if they use one hand to support the butt of the pike at the level of the shoulder and the other hand to guide the pike. *Repeat this operation until the pole can be piked directly into the hole.* When the pole commences to slide into the hole, remove the deadman so that it will not interfere with the movement of the pole. Line up pole with cant hooks or peavies and steady it with pikes while backfilling and tamping.

erecting poles depends upon the size and weight of the pole and upon conditions encountered at the pole locations. Where practicable, the cross arms should be placed before the pole is erected. The following methods are given to cover various conditions met with.

***First Method.**—Setting by pole derrick operated by power winch on automobile truck.* This method, as shown in figs. 5,855 and 5,856, will prove to be the most economical and safest way of erecting poles in practically

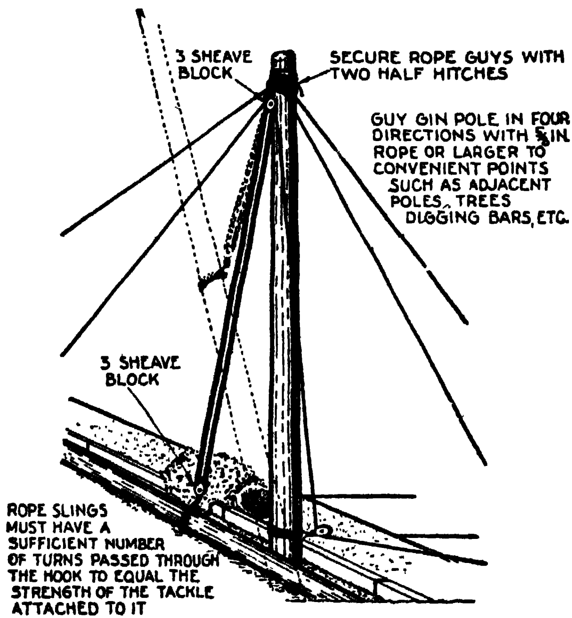


FIG. 5,858.—***Erecting poles, 3rd Method.*** Erect a gin pole of suitable length as near as practicable to the hole which has been dug for the line pole. Where there is danger that the gin pole butt will slip to one side under load, dig a shallow hole for the gin pole butt. Where there is no danger of this, the gin pole butt may be set on the ground, or on a plank if the soil be soft. Guy the gin pole as shown. Attach blocks to gin pole about 6 ins. from top of pole. Attach lower end of tackle to line pole just above *balance point*. Haul away on tackle, guiding the pole as it rises, either by pressure on the butt or by pike poles . Lower pole into hole. Line up pole with cant hooks or peavies and steady it with pikes while backfilling and tamping.

all cases where poles heavier than 25 foot cedar poles and not exceeding 45 feet in length are to be handled.

Second Method.—Setting with pikes. The success of this method, shown in fig. 5,857, and safety of the men employing it, depend upon the intelligent co-operation of the men. Each man should be assigned to a definite part of the work and should make himself proficient in it. Climbers or body belts should not be worn while piking poles. Nothing should be left under foot where it might cause men engaged in piking poles to trip

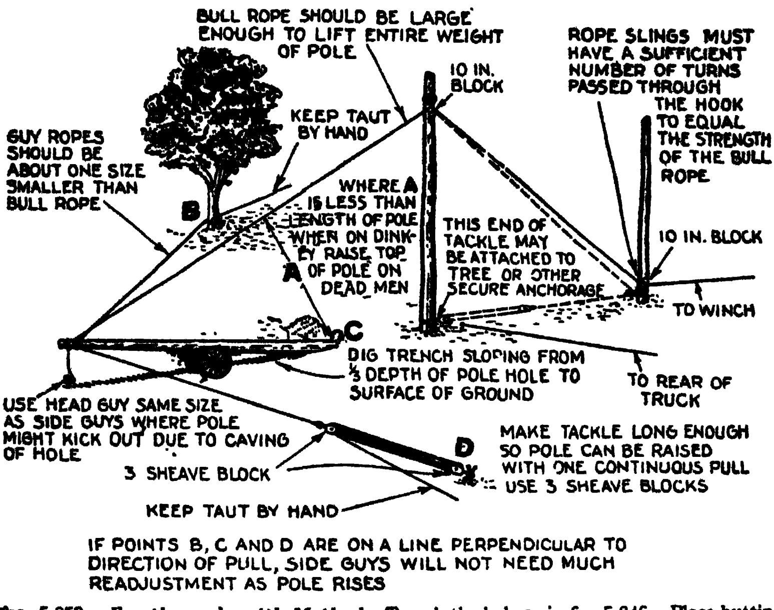


FIG. 5,859.—*Erecting poles, 4th Method.* Trench the hole as in fig. 5,846. Place butting board firmly in the hole so that it will not kick across the hole and block it. Move the pole into position so that the lower portion lies in the trench with the butt firmly against butting board. See that the anchorage, slings and tackle are in good condition and of sufficient strength. Make set up about as shown. Dotted lines show set up used where a winch is not available. Take great care to have ropes and anchorages strong enough. Serious accident might result if one of them give away. Station men to tend guy poles. Take a strain on bull rope. If top of pole tend to swing out of line of pull, bring it back by easing off or taking in slack on side guys. Haul away slowly on bull rope, keeping pole in line with pull until pole slides into hole. Line up pole with cant hooks or peavies and steady it with pikes while backfilling and tamping.

Light weight poles (25 foot cedar and smaller) may be set by hand without the use of a deadman or cant hooks. Two pike poles are sufficient. For medium weight poles proceed as explained in fig. 5,857.

Third Method.—Setting with gin pole. When the pole is too long or too heavy to use the first method, or the gang is too small to use the second method, a gin pole is used to advantage. This method is explained in fig. 5,858.

Fourth Method.—Setting with bull rope. This method may be used for heavy poles, where owing to obstruction or lack of men, other methods are not practicable. In this method a nearby pole is used to support a

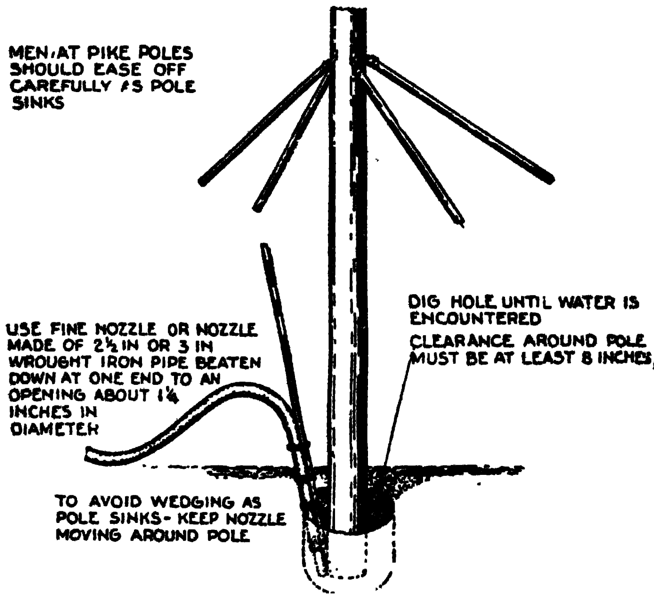
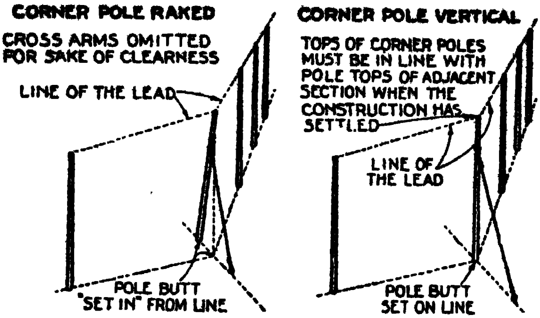
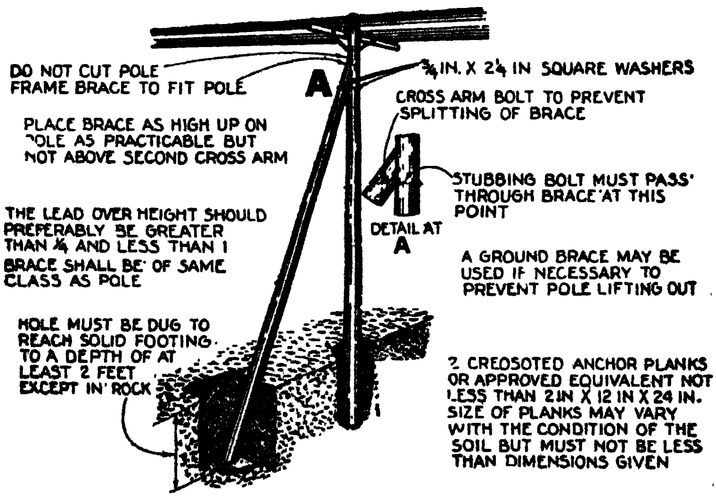


FIG. 5,860 —*Erecting poles, 5th Method.* Dig hole of sufficient diameter to give approximately an 8 in. clearance about the pole until the soil begins to cave or until water is encountered. Set pole in this hole and hold it upright with pike poles. Direct a stream of water from a nozzle lashed to a short pike pole handle into the soil at the butt of the pole. The pole is gradually undermined and sinks. During this operation move the nozzle around the butt to avoid wedging and ease off carefully on the pike poles. A pressure of 40 lbs. per sq. in. has been found to work out well with this method, although a quantity of water is more essential than a high pressure. When the pole has sunk to the desired depth, reduce the water pressure, remove the nozzle and shut off the water entirely. Shovel back the overflow of sediment around the pole. Usually no tamping is required.



FIGS. 5,861 and 5,862.—Treatment of guyed poles at corner. When placing guys, pull over tops of all poles so that when the load is put on and the anchors and guys have settled, the pole tops will have come back into line. Under average conditions pole tops should be pulled over an amount approximately equal to the diameter of the pole top. When conditions are such that more or less yield is expected from anchor and guy, this amount may be modified accordingly.



FIGS. 5,863 and 5,864.—Pole brace. Place brace as high up on pole as practicable, but not above second cross-arm. Brace hole must be dug to reach solid footing. Depth should be at least 2 ft. except in rock. Two creosoted anchor planks or approved equivalent not less than 2×12×24 ins. Size of planks may vary with the condition of the soil, but must not be less than dimensions given

snatch block for the bull rope. Where obstructions do not prevent raising pole with butt at hole proceed as in fig. 5,859.

Fifth Method.—*Setting with water jet.* Where digging hole to full depth by shovel is impracticable because of caving soil or sub-surface water, the method shown in fig. 5,860 should be used.

Rake.—Where practicable corner and dead end guyed poles should be raked by "setting in" the butts by an amount not exceeding 1 foot for every 20 feet of pole length. Conditions in towns and cities may require that all poles be set vertically. See figs. 5,861 and 5,862.

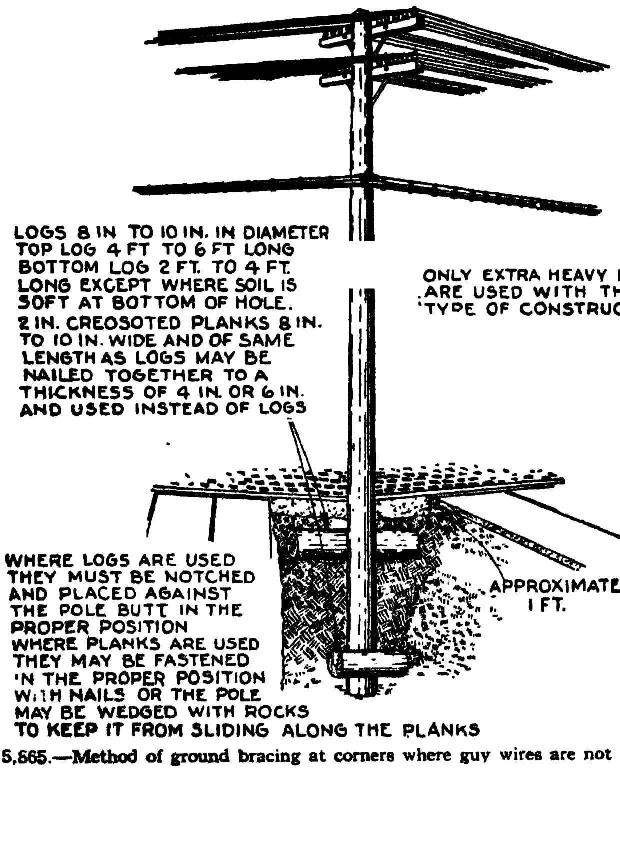
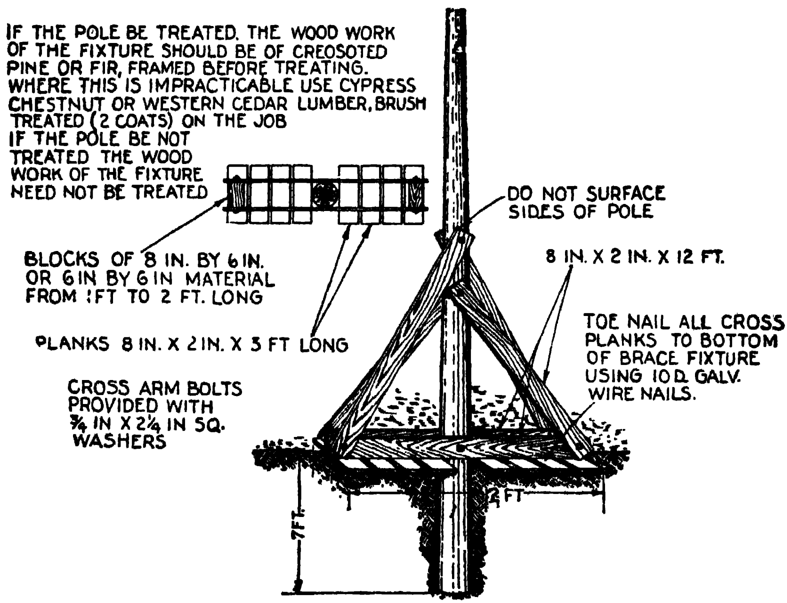


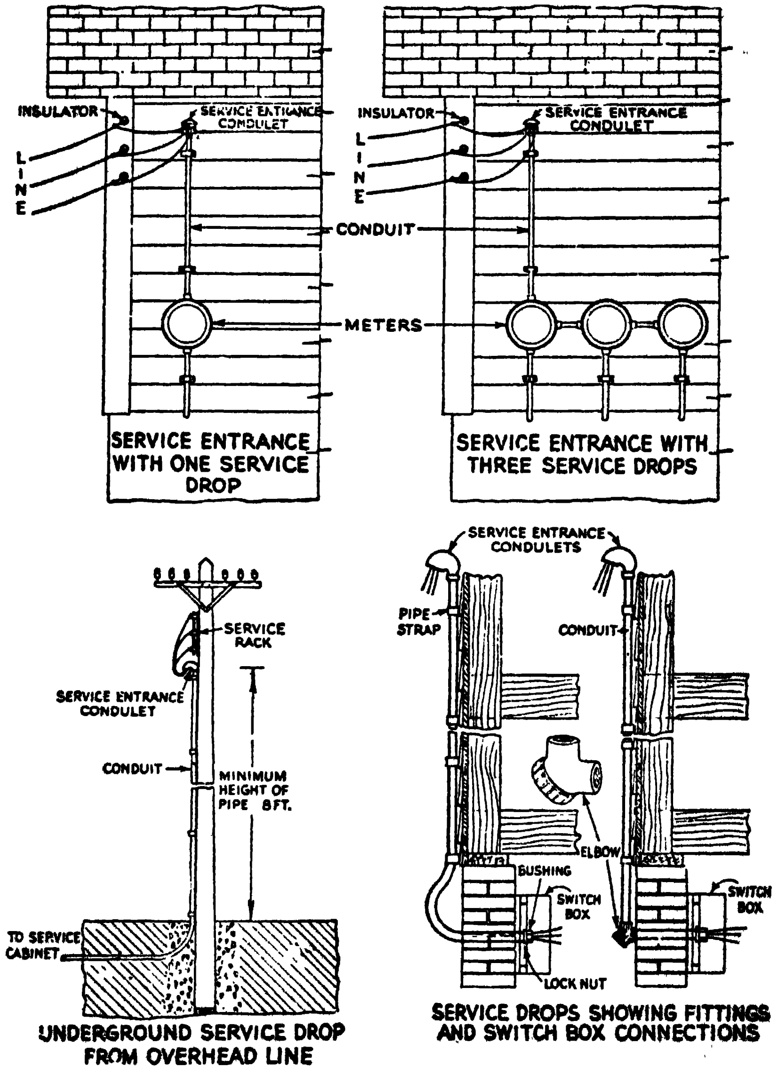
FIG. 5,865.—Method of ground bracing at corners where guy wires are not permitted.

Poles supported by pole braces should be set vertically. Ground braced poles should have their butts set in line. Their tops should be set out of line away from the *pull* by an amount equal to the *give* which is expected to take place when the pole has settled under load.

Backfilling and Tamping.—After the pole is placed in position, fill in the hole with earth, thoroughly tamping it meanwhile. Where conditions permit, use coarse soil or gravel at the top of the hole in filling. Wedge rock firmly around poles that are set in solid rock. In rural districts, bank the soil around the pole above ground level and pack it firmly. In urban districts, do not bank excess earth around the base of the pole. Cart it away.



FIGS. 5,866 and 5,867.—Swamp rig to support pole in swampy locations. Where the exposure to high winds is not great and where the earth is never extremely soft, a platform fixture without piling will generally be sufficient.



VARIOUS METHODS OF INSTALLING SERVICE DROPS

TEST QUESTIONS

1. *What should be done before starting an erecting job?*
2. *How should poles be ordered?*
3. *Where should pole storage yards be provided?*
4. *When poles are obtained locally, where should they be delivered?*
5. *Name four methods of unloading poles from cars*
6. *Describe the unloading of poles by cutting the stakes.*
7. *What may be said with respect to the storage of poles?*
8. *Describe the method of unloading poles by dragging them off the end of car*
9. *How are poles unloaded by derrick and by ropes?*
10. *How should poles be placed on highways?*
11. *What should be avoided in placing poles?*
12. *How should pole corners be located?*
13. *How should corner poles be set?*
14. *What may be said with respect to grading the line?*
15. *What is the difference between a rounded and a flat grade?*
16. *Explain the method of sighting for grading.*
17. *What is understood by "framing poles"?*
18. *Where should framing be done if possible?*
19. *How are creosoted poles delivered?*
20. *Name the five operations of framing, and describe each.*
21. *What should be provided on poles which require frequent climbing?*

22. *How high should the lowest step be placed from the ground?*

23. *Describe in great detail the various methods of erecting poles from the digging of the hole to completion.*

CHAPTER 119

Transmission Towers

With the ever increasing tendency to concentrate power house units by making fewer and larger installations, spaced farther apart, it has become necessary to transmit electrical energy over greater distances.

This involves much higher working voltages in order to reduce the transmission loss to a minimum. The use of high voltage makes necessary more efficient supports and also better insulation. Moreover, it is necessary to allow more clearance between the ground and the lowest conductor. So long as the wires were kept only a short distance above the ground, the wood poles made an ideal support for them under ordinary conditions; but when higher supports had to be considered, transmission line engineers began looking about for other supporting structures which would lend themselves more readily to all the varying conditions of service. The steel structure was immediately suggested as the proper support to take the place of the wood poles, and many arguments were advanced in its favor. However, these supports when built of steel were more expensive than the wood poles had been, and in order to keep the total cost of the line equipment down to a minimum, and to make such an installation compare favorably with a similar line using the wood poles, it became necessary to space the steel supports farther apart, so as to use fewer of them to cover the same length of line.

The structures used for supporting high tension conductors may be classed as:

1. Flexible frames;
2. Rigid towers.

Flexible Frames.—These are heavier structures than latticed poles because they are intended to take care of longer spans. Like the poles, their chief function is to take care primarily of transverse loads with a small margin of safety so that under unusual conditions of service they could also provide a little resistance in the direction of the line.

Example. — Distribute a load coming in this direction over a number of supporting structures, and transfer such a load to the still heavier structures placed at regular intervals along the line; or the flexible frames may transfer all loads coming on them in the direction of the line to a point where they will be resisted, by a frame of similar construction and strength, but which is made secure against the action of such loads by being anchored in this direction with guy lines.

Flexible frames are almost always rectangular in plan. Generally, the parallel faces in both directions will get smaller as the top is approached, but often the two faces parallel with the direction of the line will be of the same width from the bottom to the top.

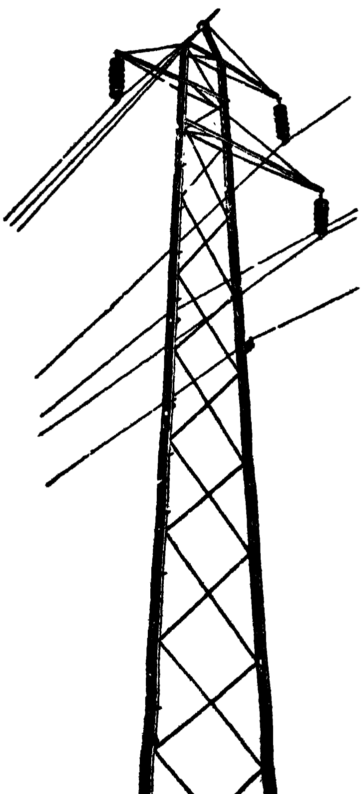
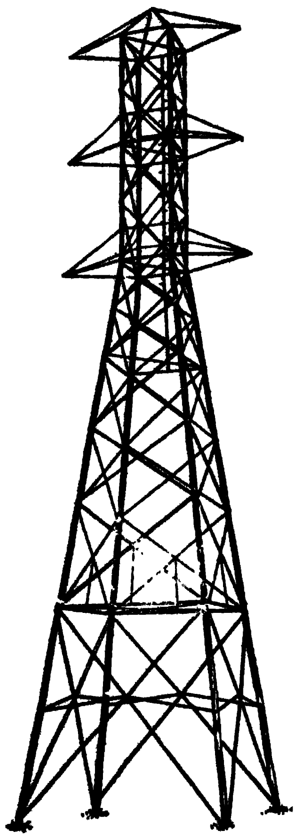


Fig. 5,868.—Flexible A frame for single circuit, 66,000 volt line.

The general appearance of a flexible frame is shown in fig. 5,868.



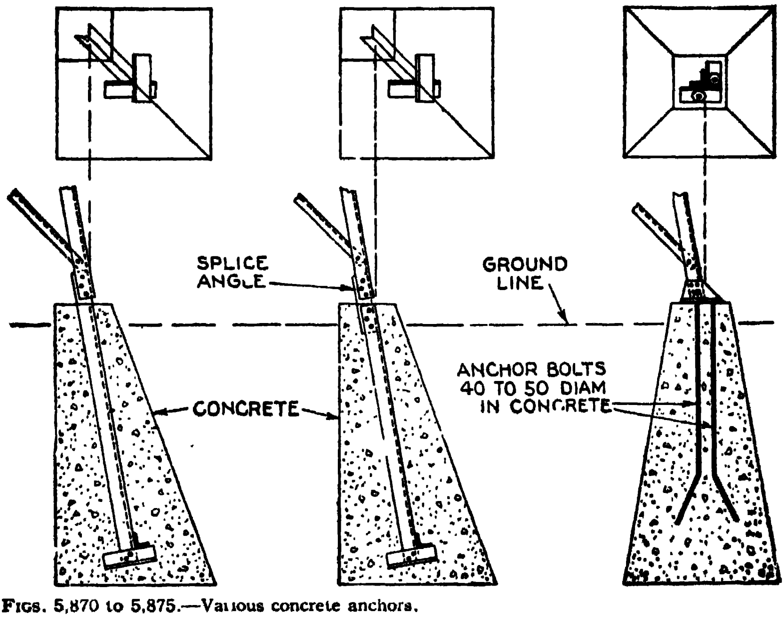
Rigid Towers.—Towers of this type commonly called transmission towers are the largest and heaviest structures made for transmission line supports, and as would be implied by the designation given them, they are intended to have strength to carry loads coming upon them, either in the direction of the line or at right angles to this direction. They are usually designed to take a combination of loads in both directions.

These towers are built in triangular, rectangular, and square types, depending upon the particular conditions under which the structure is to be used.

FIG. 5,869.—Blaw-Knox standard type transmission tower.

NOTE.—*The value of flexible frames* comes from their low cost as compared with the cost of rigid towers and the flexible feature is of value in case of isolated stresses created by storms, falling trees, etc. Where the pin type of insulator is used, the overhead ground wire is sometimes advisable, although not always essential where the flexible structures have sufficient stability to safely stand during the construction period, after which the stability of the conductors places the line in working condition.

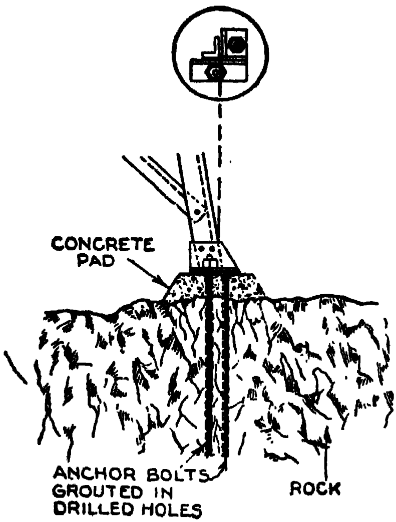
When a plan of the tower at the ground line is square in outline, each side of the square will be very much larger than in the case of either poles or flexible frames. The width of one side of a rigid tower, measured at the ground line, will vary somewhere between about one-seventh and one-third of the total height of the structure This dimension is usually determined by the construction which will give the most economical design, especially when there are a large number of the towers required; but it often happens that the outline of one or more of the structures will be determined by local conditions which are entirely foreign to the matter of economy of design. Moreover, the conditions of loading may be such as to make a special outline the most economical design. A standard type tower is shown in fig. 5,869.

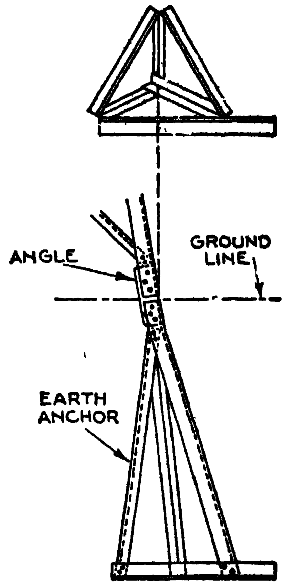


FIGS. 5,870 to 5,875.—Various concrete anchors.

NOTE.—*Transmission towers and structural poles.* A tower is generally assumed to be a large 4 legged structure, sometimes capable of being a dead end structure in itself, although usually a tower is designed more with the idea of taking care of broken wire conditions better than would an ordinary latticed pole. The types of bracing usually are different, the bracing on the latticed pole usually being made up of flats, where the bracing on a tower usually is made up of light angles or members more capable of taking compressive loads. This latter type of design in the tower is more economical construction.

Tower Anchors.—Concrete makes the best footing. The weight of the concrete itself reacts against the tendency of the post to pull away from the base because of the tension in the post on one side of the tower. It also offers more bearing surface against the earth around the footings and introduces the





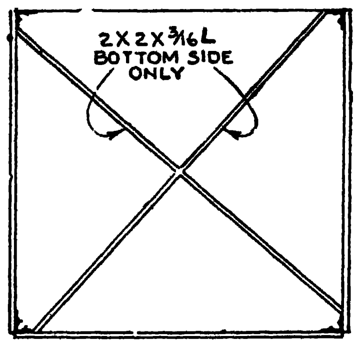
FIGS. 5,876 and 5,877.—Rock anchor.
FIGS. 5,878 and 5,879.—Earth anchor.

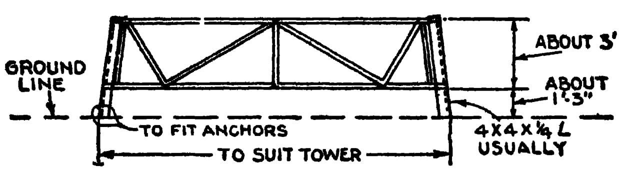
passive resistance of a larger volume of earth against the uplifting tendency of the post on the tension side of the tower.

When concrete footings are used, the posts are connected to them in one of two ways:

In the first method, extensions of the post sections, which are called anchor stubs, may be built in these footings with just sufficient length extending above the concrete so that the lower post sections of the tower

may be connected directly to them. These anchor stubs may extend almost to the bottom of the footing or they may extend into the footings only far enough so that the adhesion of the concrete to them will develop their full strength, in which case it will be necessary to add steel reinforcing bars from this point to the bottom of the concrete. This is necessary because provision must be made to bind the concrete together so that it will not break apart under the uplifting force in the post, and thus defeat its purpose.





Figs. 5,880 and 5,881.—Setting template for anchor stubs. Almost all towers are built smaller at the top than at the ground line, and the tower leg inclines from the vertical as determined by the outline of the structure, fig. 5,881. The anchor stub generally follows the direction of the main tower leg, but when it is put in this position and suspended from a template it has a tendency to swing to the vertical position. To obviate this condition the setting template should be trussed as here shown.

The second method consists in having a base at the lower end of the post section which will bear directly on the mass of concrete in the footing, and which will at the same time be connected directly to this concrete by means of long bolts or rods extending well into the mass of concrete. These rods, in this case, would be brought into action only when the post is under tension. If these rods be straight for their full length, and fairly large, they should be imbedded in the concrete for a length equal to fifty times

Fig. 5,882.—*Tower erection, first opera*

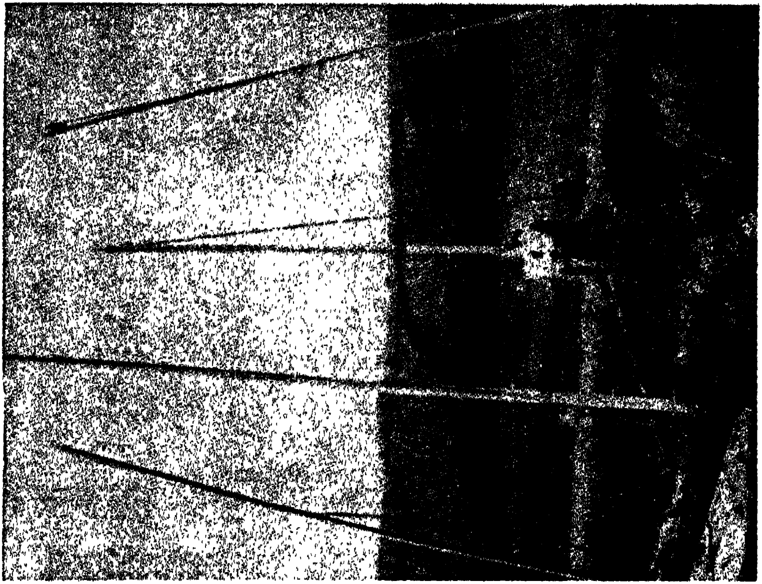


Fig 5,883.—*Tower erection, second operation.*

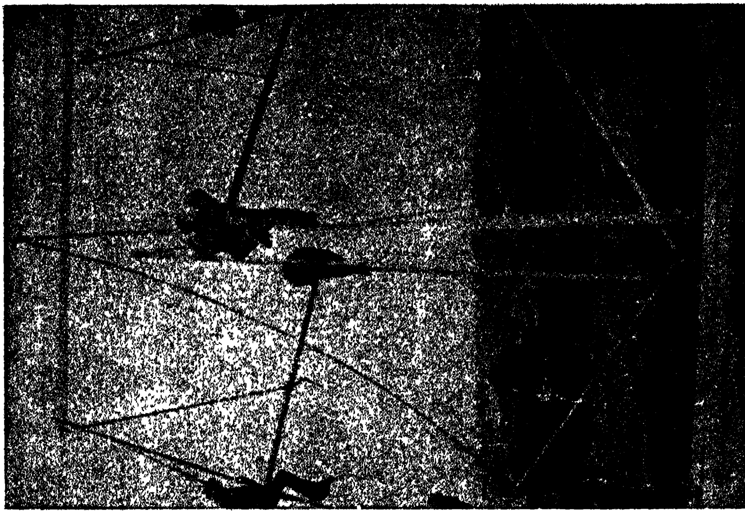


FIG. 5,385.—*Tower erection, fourth operation.*

FIG. 5,884.—*Tower erection, third operation.*

their diameter, in order to develop their full breaking strength. However, if these rods be bent a little near their lower ends, their breaking strength will be developed by imbedding them in the concrete for a length equal to forty times their diameter.

Provision for binding together the concrete in the footing must be made when anchor rods are employed, just the same as when anchor stubs are used.

Figs. 5,870 to 5,879 show various concrete, rock and earth anchors.

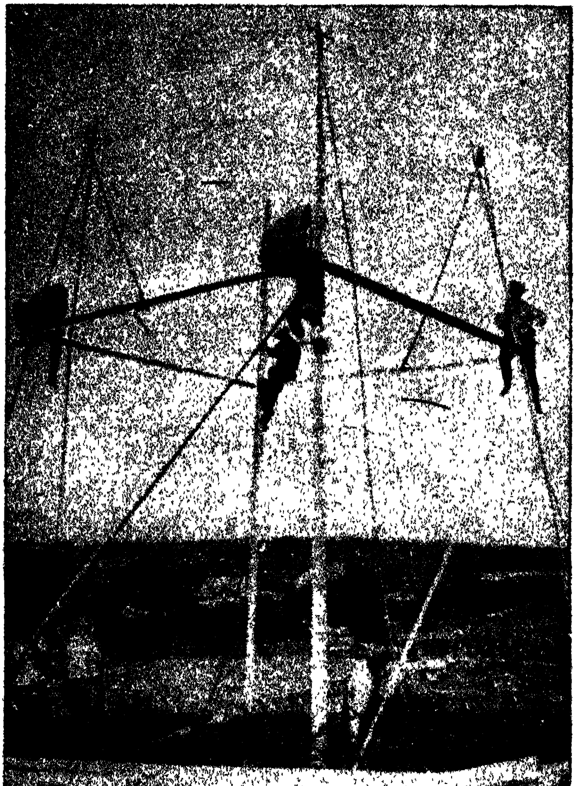


FIG 5,886.—*Tower erection, fifth operation.*

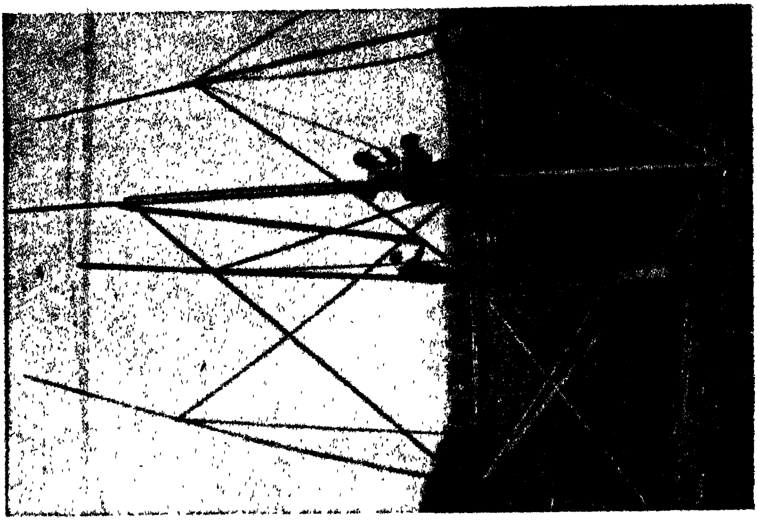


FIG. 5,888.—*Tower erection, seventh operation.*

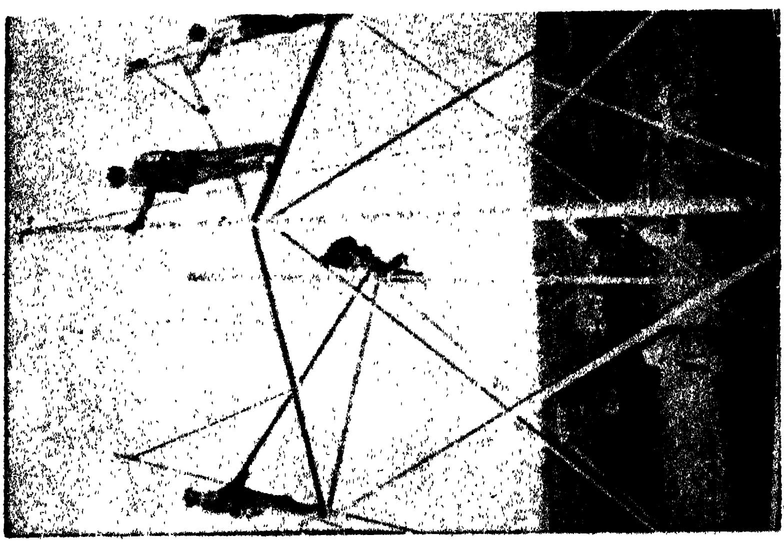


FIG. 5,887.—*Tower erection, sixth operation.*

Erection of Transmission Towers.—There are two methods by which towers may be erected:

1. Assembling in permanent position;
2. Assembling on ground.

First Method.

When a tower is assembled by the first method, that is vertically, there will generally be required a crew of eight men, including one foreman. The following equipment will generally suffice:

One light gin pole, about 25 ft. long.

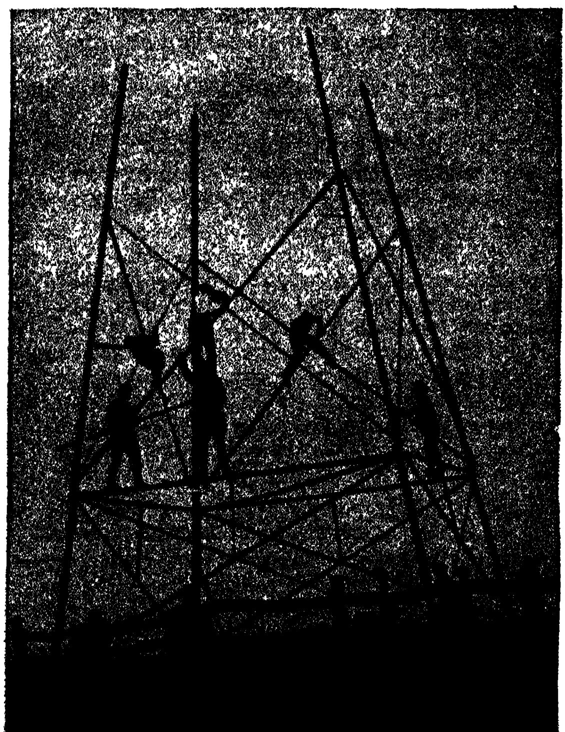


FIG. 5,889.—*Tower erection, eighth operation.*

One set of two-sheave and three-sheave blocks for ¾ in. diameter rope.

About 300 feet of ¾ in. diameter rope; four hand lines, each about 150 ft. long; four small gate blocks for the hand lines.

The post members are erected with the gin pole and tackle, but all the other members are pulled up from the ground with the hand lines. The time required will be about the same whether the tower be light or heavy. The time required will, however, depend upon both the accuracy of the fabrication of the material and the accuracy of the alignment of the anchor stubs.

Second Method.

When the tower is put together on the ground, the actual work of raising it does not consume more than ten or fifteen minutes after all the preparations have been made. These preparations and the erection consist of three distinct operations:

1. Leveling the ground where required for the erection equipment, and blocking up the tower on rough ground and for side hill extensions. A crew of seven or nine men including a foreman is required.

2. Rigging up erection equipment, and bolting erection shoes and struts in place, etc. A crew of about twelve men including a foreman is required.

3. The actual raising of the tower. Sometimes horses are used for this operation, but it is often found to be more satisfactory to use a caterpillar tractor, especially for raising the heavier towers. One team of horses will generally suffice for this work, but it often requires four and sometimes six horses, especially in rough country and for raising towers that are unusually heavy. The tractor gives a much steadier pull, and will permit of holding the load at any desired point more satisfactorily than when horses are used. A substantial A-frame usually built up of steel pipes is generally employed for raising the tower from the prone to the upright position. A steel cable should also be used in preference to a manila rope for this purpose in the case of the heavier towers.

When concrete footings are used, and this method of erection is employed, there is an advantage in having the anchor stubs set and concreted in position in advance of the assembling of the tower. When this is done, the tower can be assembled close to the anchor stub and can be

NOTE.—*When installing a line of flexible frames* with an overhead ground wire, the builder may use dead end towers, one about every mile, or may use guyed structures, one about every half mile. When a line is guyed in this manner, the head and back guys are usually designed to carry the longitudinal tension of one or more of the conductors broken. The use of guyed poles and structures, as compared with self supporting structures, is economical, and for this reason they are in general use

raised about hinges fastened to the tops of the anchor stubs; but when the tower is assembled before the concrete is placed around the anchor stubs, it is necessary to assemble the tower a few feet away from the stubs, and then to skid the tower into the position from which it is to be raised. This process of skidding the tower is costly, and is also likely to injure the tower members.

TEST QUESTIONS

1. *What are the conditions that require the use of transmission towers?*
2. *Name two classes of transmission tower.*
3. *What is a flexible frame?*
4. *Give the construction of a flexible frame.*
5. *What is the chief feature of flexible frames?*
6. *Describe the construction of a transmission tower.*
7. *Give the proportions of transmission towers.*
8. *What makes the best footing for a transmission tower?*
9. *Describe two ways of connecting a post when concrete footings are used.*
10. *Describe the operation of setting a template for anchor stubs.*
11. *Name two methods of erecting transmission towers.*
12. *How is a transmission tower erected by assembling in permanent position?*
13. *How is a transmission tower erected by assembling on the ground?*
14. *How much of a crew is required for the first method?*
15. *What equipment is used for the first method?*
16. *Does it require more time to erect a large tower than a small tower by the first method?*

17. *Name three distinct operations to be performed in the second method.*
18. *How many horses are necessary for raising a tower?*
19. *Is a tractor better than horses?*
20. *What kind of a frame is employed for raising a tower?*
21. *When the tower is assembled on the ground and concrete footings are used, what advantage is offered?*
22. *What is the objection to skidding a tower?*
23. *What are dead end towers?*

CHAPTER 120

Stringing the Wires

There are several methods of stringing the wires depending on the size of the installation, equipment available, conditions under which the work must be done, etc.

On the average job, the conditions are frequently such that the selection in advance of specific points for setting up the reels is inadvisable on account of the difficulty of predetermining the length of wire that can be strung in one pull. Also, pole lines are often so located that the reels may be set up practically anywhere along the line. In such cases, the stringing of the wire is usually started at the beginning of the line and the wire pulled out as far as practicable; then a new set-up is made.

The order in which the operations of stringing the wires as usually performed on the average job is shown in fig. 5,890. They are briefly:

1. Set up the reels at a starting point A;

2. Pull the wires out through the first section, the length of which is determined by the conditions;

3. Dead end the wires at the starting point A, and where necessary place a temporary guy on pole at end of the first section B;

4. Pull the wires to the proper tension and sag, in the first section, locating the apparatus for pulling at the end of the section B, and snub the wires at B.

5. Tie in the wires after they have been pulled up to the proper tension and snubbed.

6. Continue the operation in the succeeding sections in the same manner, except that the wires should be spliced to the wires of the preceding section instead of dead ending them as at the starting point.

7. Remove temporary head guys as the job progresses.

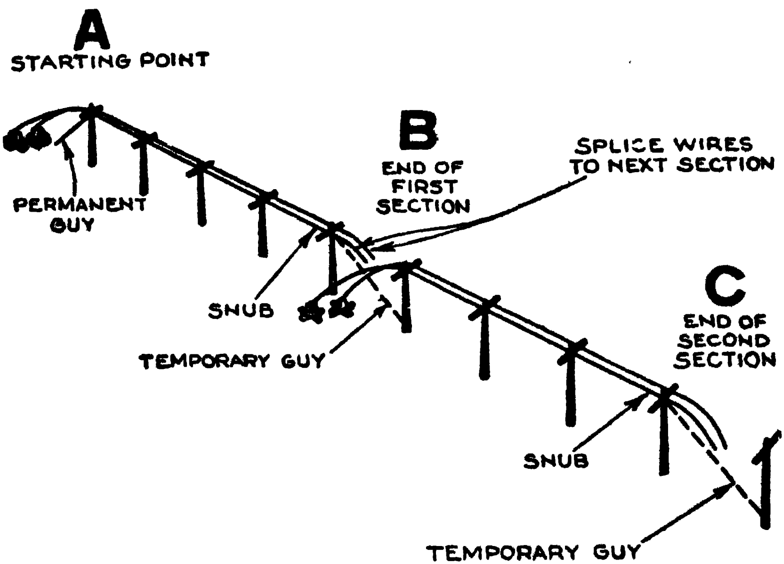


Fig. 5,890.—Diagram to illustrate method of stringing wires on the average job.

Where the conditions are such that only specific points are available for setting up the reels and it is practicable to select points from which the wire can be run out in both directions, the operations of stringing wire are usually performed as shown in fig. 5,890.

Reel Set-ups.—These will depend on various items such as,

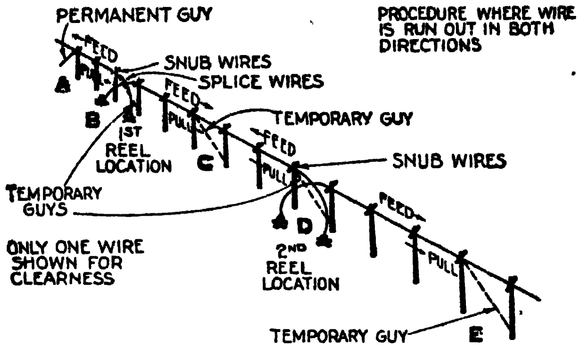


FIG. 5,891.—Diagram to illustrate method of stringing wires where the reels can be set up only at certain points. *Proceed thus*: 1, select first reel location, B, near enough to the starting point A, to permit pulling the wire back to the starting point, and at a point which will permit pulling out the wire in both directions; 2, set up the reels at first reel location B; 3, pull wires out from B, toward A, and dead end the wires at A; 4, where necessary place temporary guy at B; 5, pull wires in section AB, to proper tension from B, and snub the wires at B; 6, pull wires out from B, to C. Tie in section AB, while doing this work; 7, splice wires at B; 8, where necessary place temporary guy at C: 9, pull wires in section BC, to proper tension from point C, and snub wires at C.

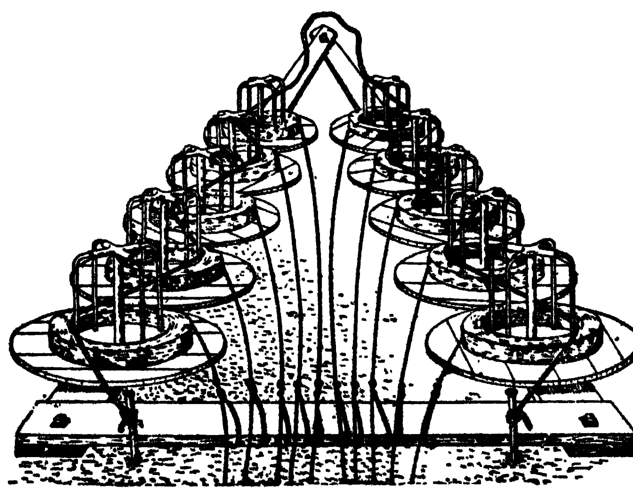


FIG. 5,892.—Multi-reel holder and brake. Use ¾ inch rope to brake the reels.

total length of wire to be strung; maximum length of wire that can be handled in one pull, etc. The arrangement of the reels depends upon the space available, method of setting up the reels and the number of wires to be pulled. Where practicable, set the reels as in fig. 5,892 and locate them far enough from the pole to permit the wires to pay out smoothly.

Pulling the Line.—Equip with a snap fastener each of the

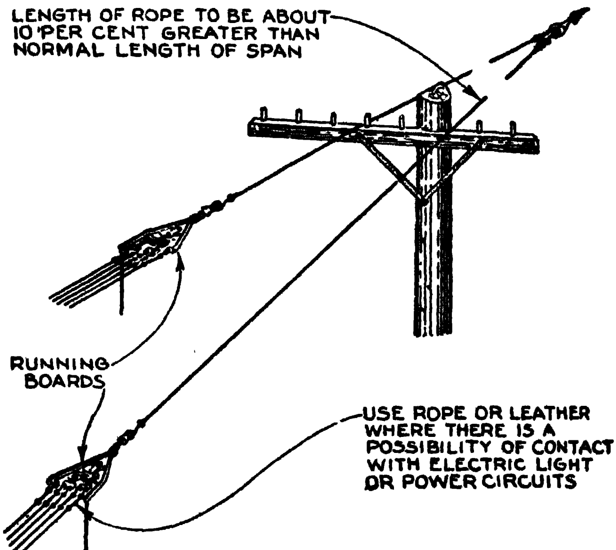


FIG. 5,893.—Apparatus for pulling the line. Where the wires being strung are near electric circuits the snap fasteners should be insulated from the wires with a piece of leather or rope. Where the circuits being strung are located on pins on opposite sides of the pole, as shown, or on different arms, the wires should be attached to two running boards, except where only one wire of a circuit is located on the opposite side of the pole. The second running board should be attached to the pulling line by a rope, each end equipped with a snap fastener. The second running board should trail the first board by a distance of about 5 ft. The use of a rope of this length on the second board permits the lineman on the advance pole to pass the second line to the other side of the pole or to the other cross arm while the lineman at the running board is fanning out the wires. The rope hanging from the running board assists in preventing the running board turning and can be used in guiding the wires from the ground.

SAG FOR 080 COPPER OR 083 GALV. STEEL (OR B.B.) WIRE

Length of Span in Feet	100°	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°	-10°
	TEMPERATURE DEGREES FAHRENHEIT — MINIMUM SAG IN INCHES											
80	7	6	5½	5	4½	4	3½	3	3	2½	2½	2
90	8½	8	7	6½	6	5	4½	4	3½	3	3	2½
100	10½	9½	8½	8	7	6	5½	5	4½	4	3½	3½
110	13	12	10½	9½	8½	7½	6½	6	5½	5	4½	4
120	15½	14	12½	11	10	9	8	7	6½	5½	5	5
130	18	16½	14½	13	12	10½	9	8	7½	6½	6	5½
140	21	19	17	15	14	12	10½	9½	8½	8	7	6½
150	24½	22	19½	17½	16	14	12	11	10	9	8	7½
160	27½	25	22	20	18	16	14	12½	11	10	9½	8½
170	31	28	25	22½	20½	18	15½	14	12½	11½	10½	9½
180	35	31½	28	25	23	20	17½	15½	14	13	12	11
190	39	35	31	28	25½	22½	19½	17½	15½	14½	13	12
200	43	39	34½	31	28½	25	21½	19½	17½	16	14½	13½
210	47½	43	38	34	31½	27½	24	21½	19½	17½	16	14½
220	52	47	41½	37½	34½	30	25½	23½	21	19½	17½	16
230	57	51½	45½	41	37½	33	28½	25½	23	21	19½	17½
240	62	56	49½	44½	41	35½	31	28	25	23	21	19½
250	67½	60½	53½	48½	44½	38½	33½	30½	27	24½	23	21

SAG FOR 165 OR 104 COPPER WIRE AND 165 OR 109 GALV. STEEL (OR B.B.) WIRE OR LARGER

Length of Span in Feet	100°	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°	-10°
	TEMPERATURE DEGREES FAHRENHEIT — MINIMUM SAG IN INCHES											
80	6	5½	5	4½	4	3½	3	2½	2½	2½	2	2
90	7½	7	6	5½	5	4½	4	3½	3	3	2½	2½
100	9½	8½	7½	6½	6	5½	5	4½	4	3½	3½	3
110	11½	10	9	8	7	6½	6	5	5	4½	4	3½
120	13½	12	10½	9½	8½	7½	7	6	5½	5	4½	4½
130	16	14	12½	11½	10	9	8	7	6½	6	5½	5
140	18½	16½	14½	13	11½	10½	9½	8½	7½	7	6½	6
150	21½	19	17	15	13½	12	11	9½	9	8	7½	7
160	24	21½	19	17	15	13½	12½	11	10	9	8½	8
170	27½	24	21½	19½	17	15	14	12½	11½	10½	9½	9
180	30½	27	24	22	19	17	15½	14	12½	11½	10½	10
190	34	30	27	24½	21½	19	17½	15½	14	13	12	11
200	38	33½	30	27	23½	21	19	17	15½	14½	13	12½
210	41½	37	33	30	26	23½	21	19	17½	16	14½	13½
220	46	40½	36	32½	28½	25½	23	20½	19	17½	16	15
230	50	44	39½	35½	31½	28	25½	22½	21	19	17	16
240	54½	48	43	39	34	30½	27½	24½	22½	21	19	17½
250	59	52	46½	42	37	33	30	26½	24½	22½	20½	19
275	71½	63	56½	51	44½	40	36	32	30	27	24½	23
300	85	75	67	60½	53	47½	43	38½	35½	32½	29½	27½

*NOTE.—*In running out wires along the ground*, the reels may be placed on a truck, allowing the wires to pay out while the truck or wagon is moving ahead, or the wires may be pulled out along the ground with the reels at a fixed location.

wires to be pulled. The wires shall be fastened to a running board as shown in fig. 5,893 so that the wires can be transposed readily. Equip end of pulling line with a snap fastener.

The wire may be run out, either

1. Over the cross arms, or
2. Along the ground.

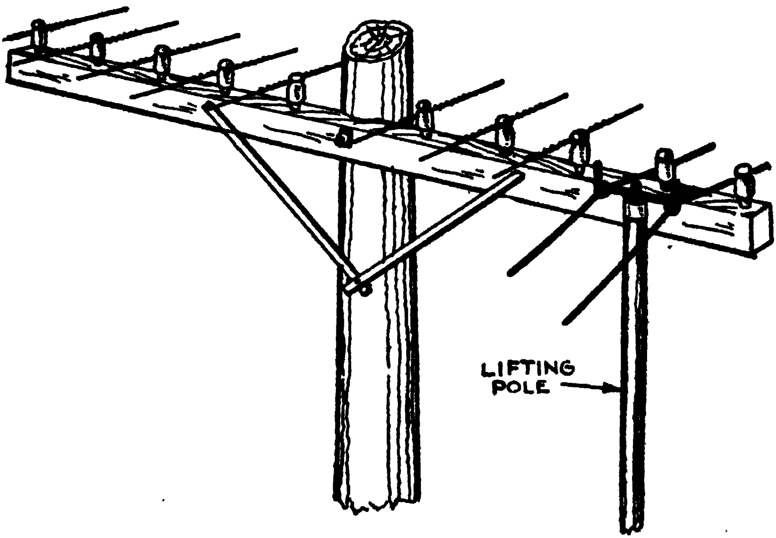


FIG. 5'894.—Lifting pole for raising wires to cross arm.

Where the poles are short and only a few circuits are to be strung and it is practicable to run the wires out along the ground, a wire raising tool may be used, as shown in fig. 5,894.

When pulling the wires use pulling blocks, strain equalizing blocks and tackle as shown in fig. 5,895. Do not pull wires of different sizes with the apparatus shown.

Snubs.—The word *snub* as here used means *to hold fast.*

When it is desired to hold the strain on wire that has just been pulled so that it may be tied in, or to hold the strain on wire while it is being spliced, the wire should be snubbed as shown in fig. 5,896. Where an unbalanced strain would exist on the pole, a temporary guy should be placed before pulling up the wire.

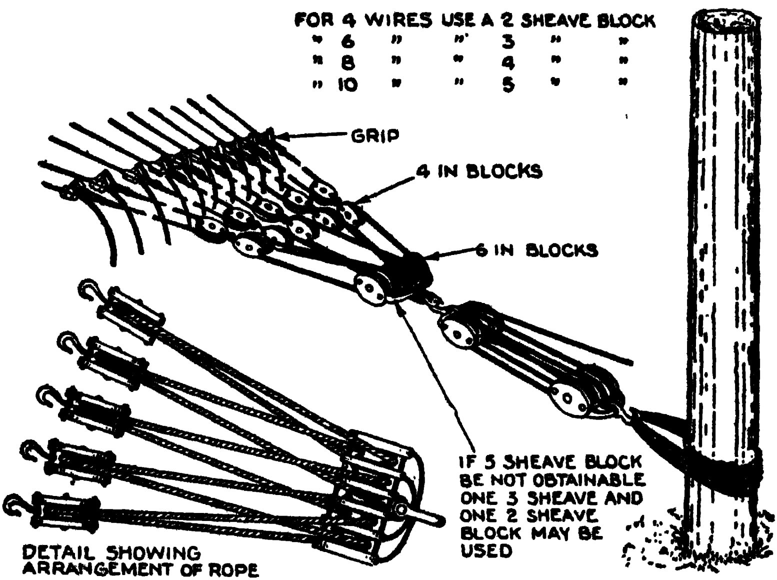


FIG. 5,895.—Pulling apparatus for pulling a number of wires of the same size.

Sag.—By definition sag is *the extent to which a wire dips by its own weight at the middle of the span between two points of support.* In pole line wiring the point at which the sag is measured depends upon whether the ground be level or sloping as indicated in figs. 5,897 and 5,898.

The tables on page 3,527 give the sag for the different sizes of wire.

Properties of Wires

BARE COPPER WIRE

SIZE	STANDARD COIL: MAXIMUM LENGTH IN FEET	STANDARD COIL: MAXIMUM WEIGHT IN LBS.	STANDARD COIL: MINIMUM LENGTH IN FEET	STANDARD COIL: MINIMUM WEIGHT IN LBS	FEET OF WIRE PER LB.	APPROX. WEIGHT PER MILE IN LBS.
080 COPPER WIRE	4400	85	2750	53	51.8	102
104 COPPER WIRE	7950	260	2960	97	30 5	173
165 COPPER WIRE	3160	260	1850	152	12.1	435

BARE IRON WIRE

SIZE	STANDARD COIL: APPROXIMATE LENGTH IN FEET	STANDARD COIL: APPROXIMATE WEIGHT IN LBS.	FEET OF WIRE PER LB.	APPROXIMATE WEIGHT PER MILE IN LBS.
083 GALV B.B.WIRE	2640	50	53.3	99
109 GALV.B.B.WIRE	2640	85	31	170

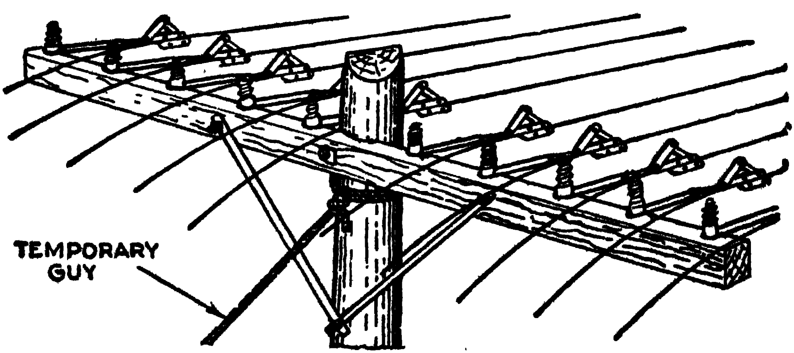
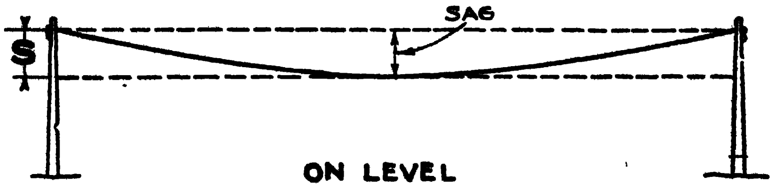
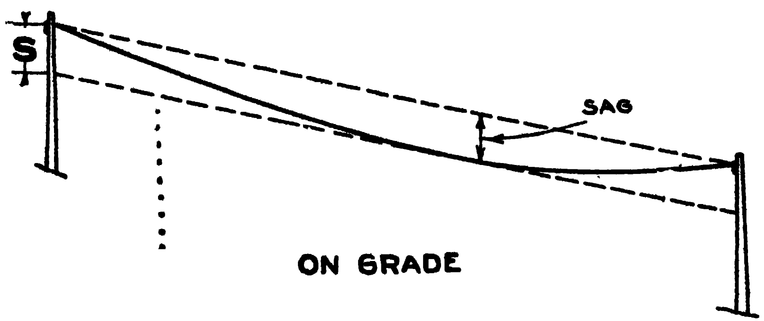


Fig. 5,896.—Method of snubbing wires with "come [illegible]." The tension is taken by the loop straps which are placed over the insulator pins.

The amount of sag is a direct indication of the tension in the wire. A simple and accurate method of measuring sag is by the use of targets placed on the poles below the cross arm as shown in fig. 5,899. The lineman sights from one target to the other. The tension of the wire is then increased or decreased until the lowest point on the wire coincides with the line of sight.





Figs. 5,897 and 5,898.—Sag on level and on grade.

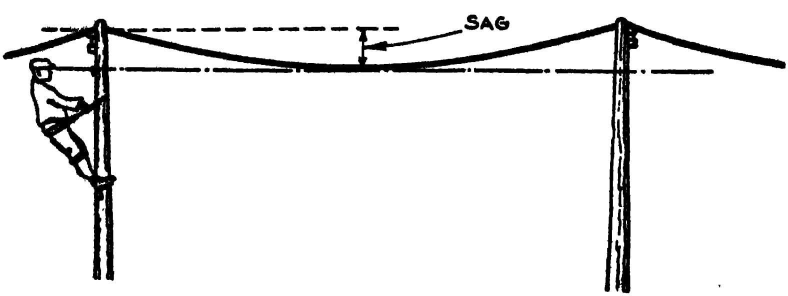


Fig. 5,899.—Target method of measuring sag.

Location of Circuits.—As far as possible, wires and circuits should be kept in the same position on the poles in order to facilitate the tracing of circuits, and to prevent accidents due to misunderstanding as to the service the various wires on the pole supply.

A rule often followed in stringing power lines, to identify the phases of a three phase circuit is as follows:

When the lineman standing under a circuit has his back to the source of power (sub-station or generating station) phase A, should be the left hand conductor, phase B, the middle conductor, and phase C, the right hand conductor. The circuit thus runs ABC, from left to right.

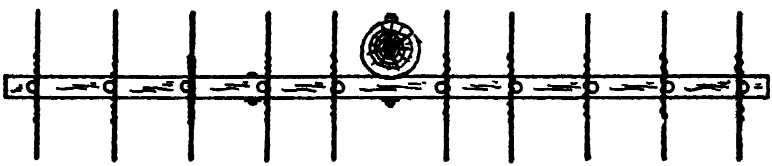


FIG. 5,900.—*Position of wires on insulators.* 1. Straight lines.

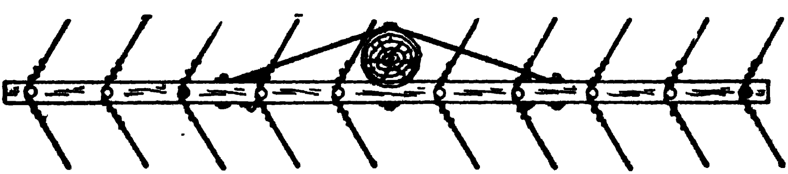
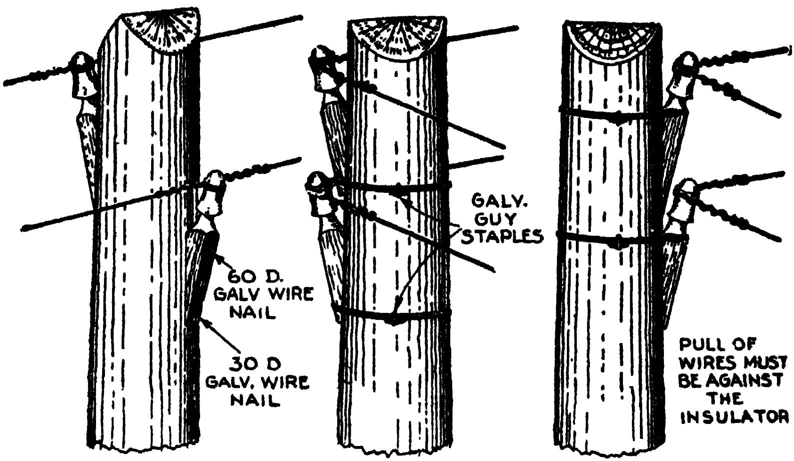


FIG. 5,901.—*Position of wires on insulators.* 2. Curves or corners.

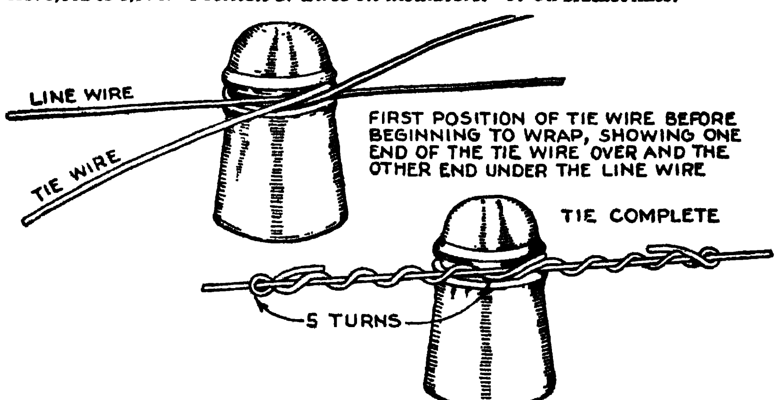
Furthermore, the conductors of a given circuit should be grouped together. In case of a three wire secondary circuit on cross arms, the neutral wire should be located in the middle of the other two wires.

In case of a three phase four wire feeder, the neutral wire should be placed next to the pole. One line wire should be placed on the same side as the neutral and other two line wires on the other side of the pole. On alley or side arms, the high voltage circuits should be placed on the ends of the arms and the low voltage circuits near the pole. In this way the danger of accidents is greatly reduced.

Position of Wires on Insulators.—On straight sections tie the wires to the insulator in the position shown in fig. 5,900, except where wires are displaced due to transposition or shifting of pins.



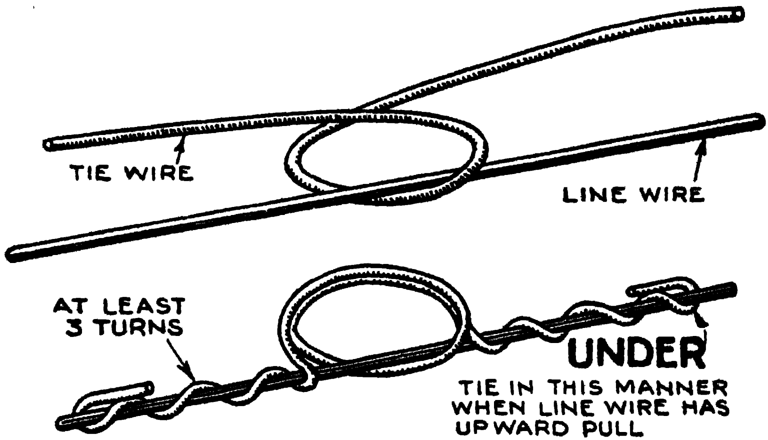
FIGS. 5,902 to 5,904.—*Position of wires on insulators.* 3. On bracket lines.



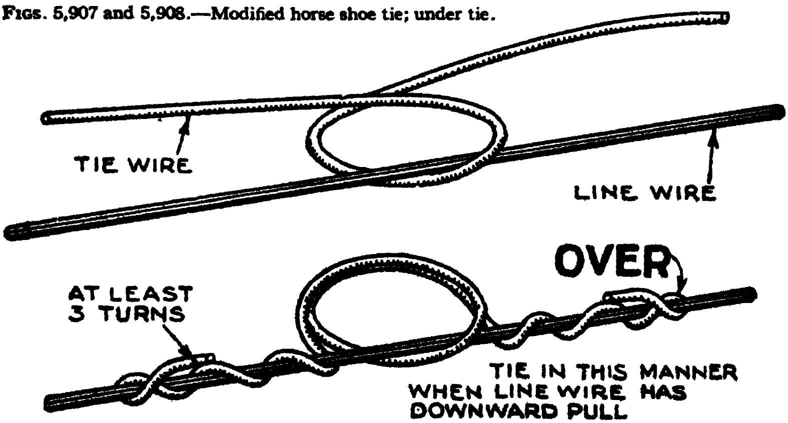
FIGS. 5,905 and 5,906.—Standard tie for copper wire. Fig. 5,905 first position; fig. 5,906 tie completed.

In these latter cases, tie the wires so that they will pull against the insulators. On curves and corners tie the wires to the insulators so that the pull of the wires will be against the insulators, as in fig. 5,901. Where necessary, shift pole pins to prevent wires bearing against pole.

All wires at transposition poles and at poles adjacent to



Figs. 5,907 and 5,908.—Modified horse shoe tie; under tie.

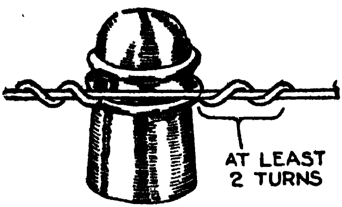


Figs. 5,909 and 5,910.—Modified horse shoe tie; over tie.

transposition poles should be tied so as to pull against the insulator.

On bracket lines tie the wires on the side of the insulators toward the pole, except where the insulators are on the outside of corner pole. In the latter case, tie the wires so that they will pull against the insulators.

Tying.—Copper line wire must be tied to the insulator with copper tie wire as shown in figs. 5,907 to 5,910. Fig. 5,911 shows method of tying galvanized iron and steel wires.



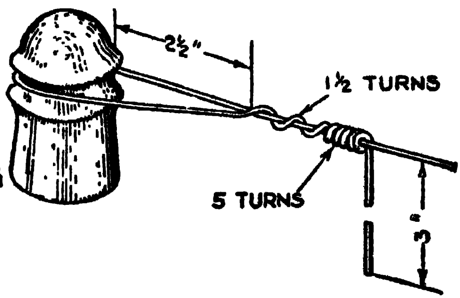
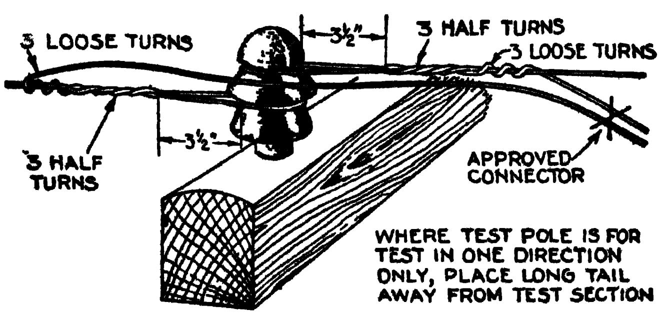


FIG. 5,911.—Standard tie for galvanized iron or steel wires.

FIG. 5,912.—Dead end for iron wire.



. 5,913.—Dead ends at test points of transposition insulators.

Size of Tie Wire.—The following table gives the proper size of tie wire to be used with conductors of various sizes:

Size of Wires

Size of Line Conductor (B. & S. Gauge)	Size of Tie Wire (B. & S. Gauge)
No. 4 and smaller	No. 6
No. 1 to No. 4	No. 4
No. 0 and larger	No. 2

NOTE.—*The tie wire*, in general, should be of the same kind of wire as the line wire. If the line wire be a bare conductor, the tie wire should be bare also, and if the line conductor be insulated, the tie wire should also be insulated. Copper tie wires should be used with copper line conductors, and aluminum tie wires with aluminum line conductors. The tie wires, however, should always be made of soft annealed wire as hard drawn tie wire would be too brittle and could not be wrapped snugly. A hard tie wire might also injure the line conductor

Equivalents

Length

To convert	Multiply by	To convert	Multiply by
Inches to mils	1,000.	Mils to inches	.001
Inches to millimeters	25.4	Millimeters to inches	.03937
Inches to centimeters	2.54	Centimeters to inches	.3937
Inches to meters	.0254	Meters to inches	39.3701
Feet to centimeters	30.48	Centimeters to feet	.03281
Feet to meters	.3048	Meters to feet	3.2808
Yards to centimeters	91.44	Centimeters to yards	.01094
Yards to meters	.9144	Meters to yards	1.0936
Yards to kilometers	.0009144	Kilometers to yards	1,093.6
Miles to meters	1,609.34	Meters to miles	.0006214
Miles to kilometers	1.6093	Kilometers to miles	.6214

Equivalents—*Continued*

Volume

To convert	Multiply by	To convert	Multiply by
Cu. ins. to cu centimeters	16.3862	Cu. centimeters to cu. ins.	.06103
Cu. ins. to liters	.01639	Liters to cu. ins.	61.024
Cu. ft. to liters	28.317	Liters to cu. ft.	.03531
U. S. bushels to bushels (Eng.)	.9688	Bushels (Eng.) to U. S. bushels	1.032
Cu. ins. to U. S. bushels	.000465	U. S. bushels to cu. ins.	2,150.4
Cu. ft. to U. S. bushels	.8035	U. S. bushels to cu. ft.	1.244
Liters to U. S. bushels	.02838	U. S. bushels to liters	35.24
U. S. gals. to Imperial (Eng.) gals.	.8336	Imp. (Eng. gals.) to U. S. gals.	1.1997
Cu. ins. to U. S. gals	.00433	U. S. gals. to cu. ins.	230.98
Cu. ft. to U. S gals	7.482	U. S. gals. to cu. ft	.1336
Liters to U. S. gals	.2642	U. S. gals. to liters	3.785

Weight

To convert	Multiply by	To convert	Multiply by
Grains to grams	.0648	Grams to grains	15.432
Ounces to grams	28.3495	Grams to ounces	.03527
Ounces to kilograms	.02835	Kilograms to ounces	35.274
Pounds to grams	453.59	Grams to pounds	.002205
Pounds to kilograms	.4536	Kilograms to pounds	2.2046
Tons (long) to tons (short)	.8929	Tons (short) to tons (long)	1.12
Tons (short) to kilograms	907.19	Kilograms to tons (short)	.001102
Tons (long) to kilograms	1,016.047	Kilograms to tons (long)	.0009842

Equivalents—*Continued*

Power

To convert	Multiply by	To convert	Multiply by
Horse power to watts	*746.0	Watts to horse power	.001341
Ft. lbs. per sec. to watts	1.356	Watts to ft. lbs. per sec.	.7375
Ft. lbs. per sec, to *h.p.*	.001818	*h.p.* to ft. lbs. per sec.	550.0
Ft. lbs. per min. to watts	.0226	Watts to ft. lbs. per min.	44.25
Ft. lbs. per min. to *h.p.*	.0000303	*h.p.* to ft. lbs. per min.	33,000.0
Kilogram-meter per sec. to watts	9.807	Watts to kg. meters per sec.	.1020

*This value depends on gravitational force at different latitudes and is
746 at latitude of London
736 at latitude of Berlin
745.7 for latitude 45°.

Miscellaneous Factors

To convert	Multiply by
Resistance at 20° C. to resistance at 60° F	.9827
Resistance at 60° F. to resistance at 20° C	1.0176
Ohms per kilometer to ohms per 1000 feet	.3048
Ohms per 1000 feet to ohms per kilometer	3.2808
Pounds per 1000 feet to kilograms per kilometer	1.488
Kilograms per kilometer to pounds per 1000 feet	.6719

TEST QUESTIONS

1. *Is there more than one method of stringing the wires?*
2. *What are the conditions met with on the average job?*
3. *What is the order in which the operations of stringing the wires are usually performed?*
4. *Upon what does the reel set ups depend?*
5. *Draw a diagram illustrating method of stringing wires where the reels can be set up only at certain points.*
6. *Describe an apparatus for pulling the line.*
7. *What is a snap fastener?*
8. *How should wires be run out along the ground?*
9. *What should be used in pulling wires?*
10. *What is a snub?*
11. *Define the term sag.*
12. *Describe the method of snubbing wires used with come alongs.*
13. *What does the amount of sag signify?*
14. *Give a simple and accurate method of measuring sag.*
15. *What may be said with respect to the location of circuits?*
16. *Give a rule often followed in stringing power lines.*
17. *Describe the position of wires on insulators*
18. *How are transpositions made?*
19. *How should wires be tied to insulators?*
20. *How are ties made on bracket lines?*

21. *Give the method of making a dead end.*
22. *What size tie wires should be used?*
23. *Should the tie wire be of the same material as the line wire?*

CHAPTER 121

Catenary Construction

The catenary system derives its name from the curve formed by a flexible cable suspended between two supports and in its

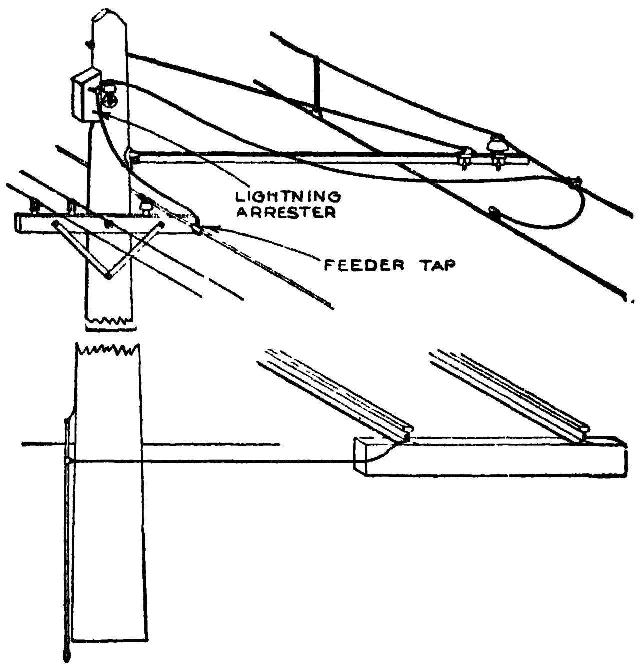


FIG. 5,916.—*Catenary construction I.* Bracket construction, lightning arrester and feeder tap.

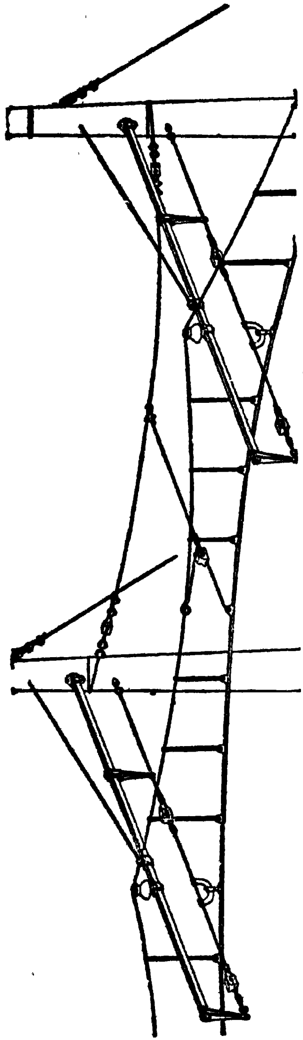
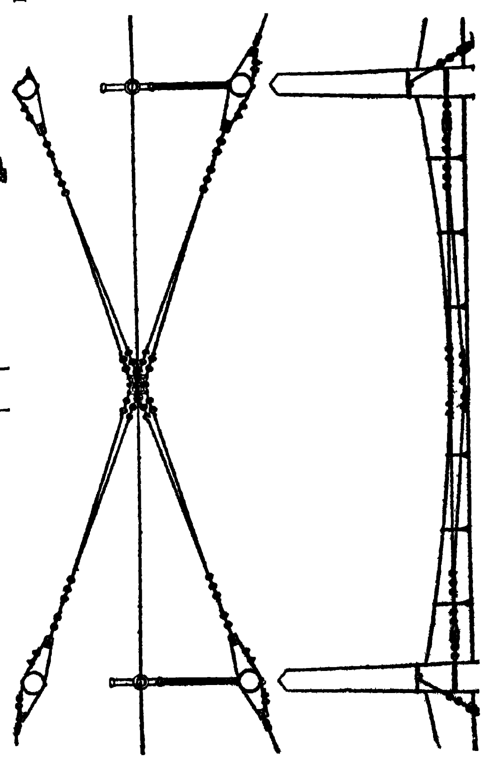


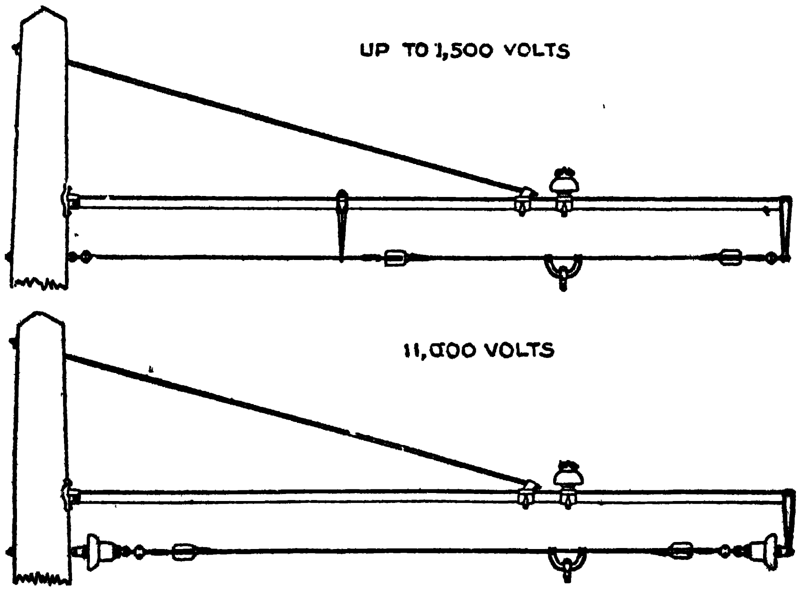
FIG. 5,917.—*Catenary construction 2.* Single track bracket construction on curves showing pull off wires between poles.



FIGS. 5,918 and 5,919.—*Catenary construction 3.* Method of anchoring with strain plates.

simple form consists of a steel messenger cable supported on insulators and thus forming a catenary curve.

The catenary system of line construction, although developed for high voltage roads, possesses so many desirable characteristics from the operating standpoint that it has wide application for all types of electric traction.



FIGS. 5,920 and 5,921.—*Catenary construction 4.* Steady construction for tangent or curves. Fig. 5,920, up to 1,500 volts; fig. 5,921, 11,000 volts.

Catenary construction is well adapted for the efficient insulation of voltages much in excess of present practice; it affords the best current collection for all types of wheel or slipper collectors at any speed and lends itself to the mechanical requirements of long spans and multiple track and yard layout. When well installed it has long life and gives efficient service with low maintenance.

A catenary construction consisting primarily of a single steel

messenger cable and a copper contact wire supported by brackets or cross spans spaced 150 feet apart on tangent tracks, with contact wire supported from the messenger wire every 30 feet is the simplest and most economical form of construction for the modern interurban line using wheel collectors and having car speeds of 40 miles per hour or higher.

Modifications of this simple construction, to meet the requirements of

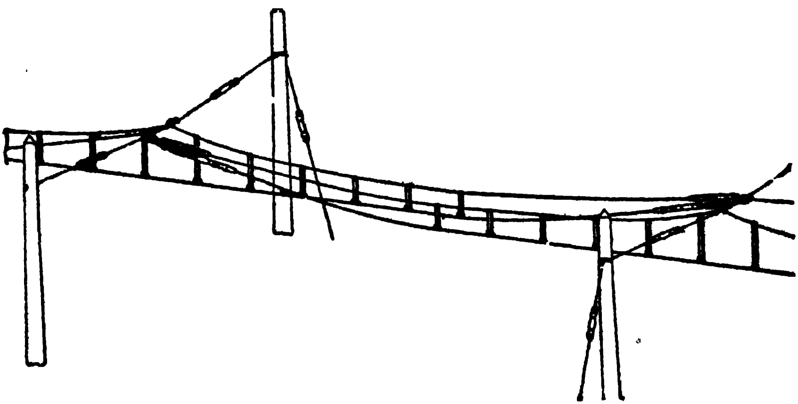
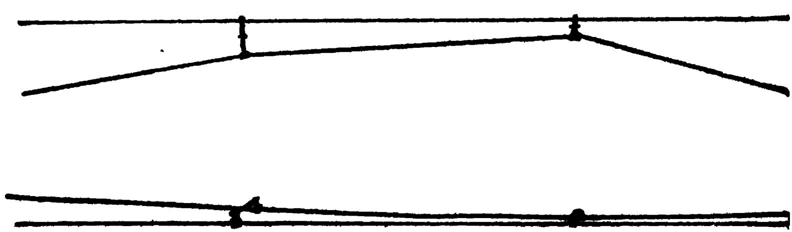


FIG. 5,922.—*Catenary construction 5.* Span anchor construction for pantograph collector showing a method of sectionalizing and anchoring a span line for pantograph collectors only.



FIGS. 5,923 and 5,924.—*Catenary construction 6.* Connecting links for turn outs and crossings. The rigid and adjustable pull off links are for use in holding the trolley wire in position at turn out and crossing points on the line, providing a smooth transition of the pantograph collector from one wire to the other. The rigid links are 8 inches long and several may be used to parallel the wires if the divergence angle be small. By using various lengths of pipe, the adjustable links are made up to span the decreasing distance between the wires approaching the point of crossing or turn out.

higher speeds and pantograph collectors used in heavy interurban and trunk line service, are made by shortening the distances between the contact wire supports to 15 feet, which will result in a perfectly level runway for the pantograph collector.

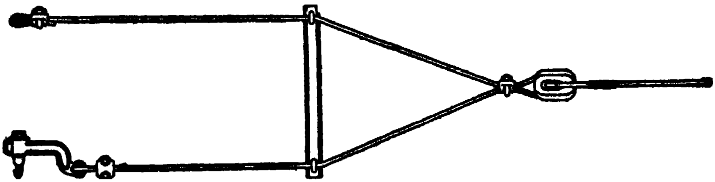


FIG. 5,925.—*Catenary construction 7.* Pull off spreader with pull over yoke for trolley wheel.

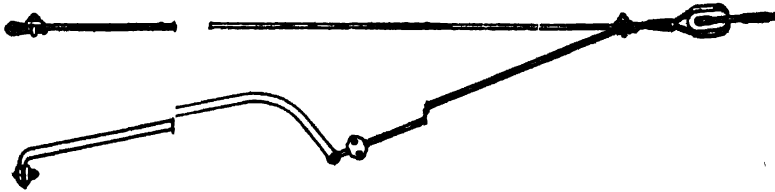
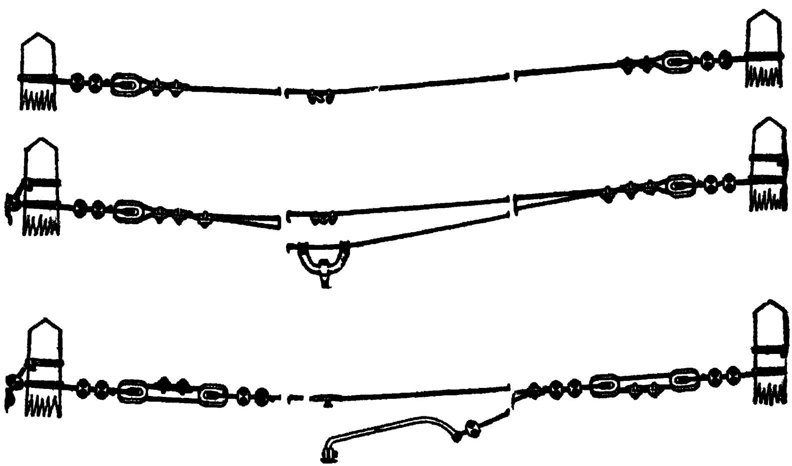


FIG. 5,926.—*Catenary construction 8.* Flexible pull over for pantograph.



FIGS. 5,927 to 5,929.—*Catenary construction 9.* Catenary cross spans for single track. Fig. 5,927, for tangent track single insulation; fig. 5,928, for tangent or curve steady construction; fig. 5,929, for curve pull off, double insulation.

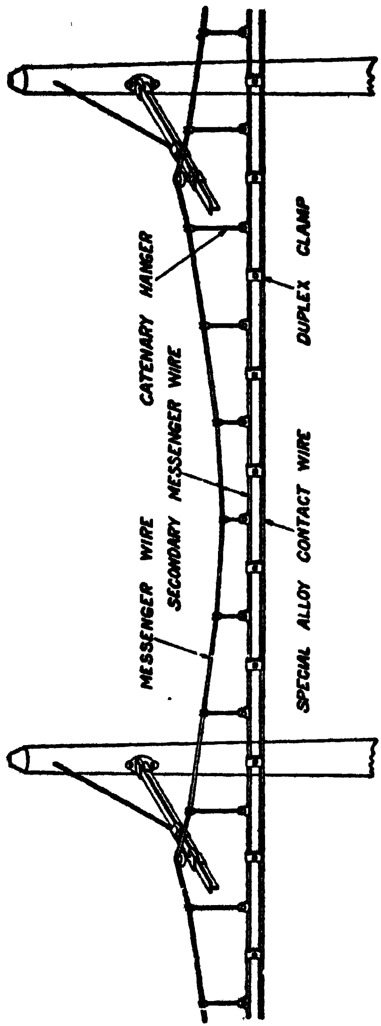


FIG. 5,930.—*Catenary construction 10.* Duplex catenary with names of parts.

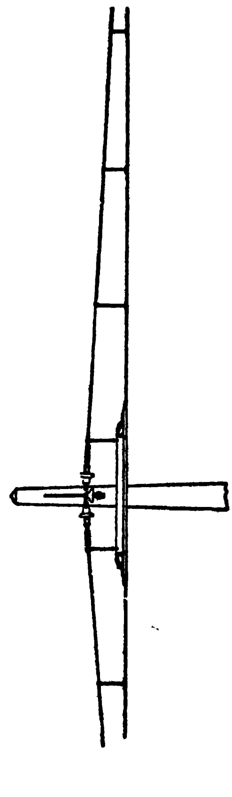
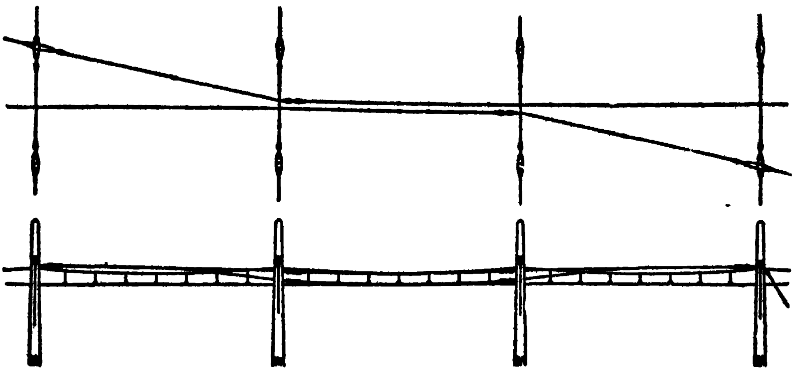


FIG. 5,931.—*Catenary construction 11.* Method of installing catenary section insulators.

Further modifications are in service, such as the use of a copper messenger wire which acts as a feeder wire, as well as steel or bronze contact wires which give increased strength and wearing qualities to the contact wires.

In the catenary system the trolley or slipper wire is suspended below the steel messenger cable by hangers at short intervals and of such lengths that the trolley wire is a straight line without sag.

There are various modifications of the simple construction such as the



Figs. 5,932 and 5,933.—*Catenary construction 12.* Method of sectionalizing line showing air break anchor construction.

use of a copper or aluminum feeder for the messenger or a steel or alloy slipper wire hung from the copper trolley wire to take the wear and introduce a small degree of flexibility where rigid hangers are used.

Compound catenary consists of a track messenger strand supported by insulators which are suspended from a main grounded messenger supported on bridges.

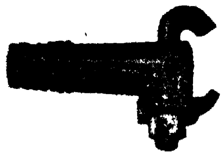
There are other combinations which have been developed to meet certain conditions but the best practice ordinarily is to keep the construction as simple as possible.

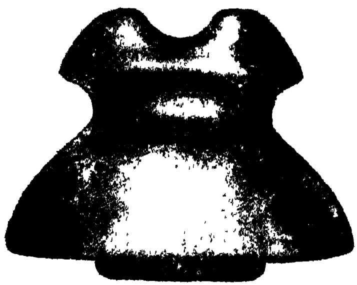
In flexible construction, the hanger which suspends the trolley from the

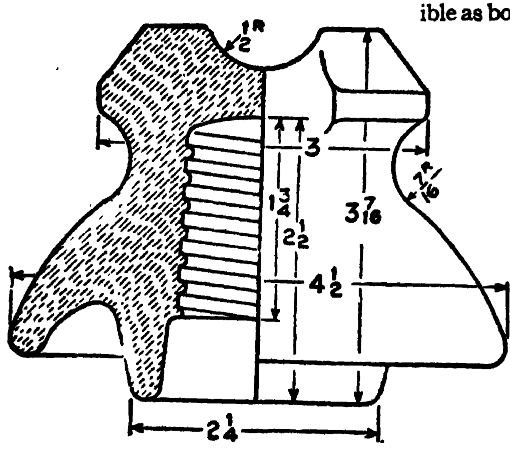
messenger is gripped to the trolley wire and loosely looped over the messenger to permit a free movement of the trolley vertically.

In rigid construction, the hangers are rigidly attached to both the messenger and the trolley. As such construction tends to produce "hard spots" in the trolley at hanger points it is customary to suspend a slipper wire below the trolley at points intermediate of the hangers thus giving just enough flexibility to remove the "hard spots." Both constructions are in successful use and both have points of merit; in designing a new line care should be used not to have it too rigid or too flexible as both extremes lead to trouble.

For the heaviest construction, the introduction of a second or auxiliary messenger wire permits an increase in the distances between the line supports, which may be steel bridges from 240 to 300 feet apart.







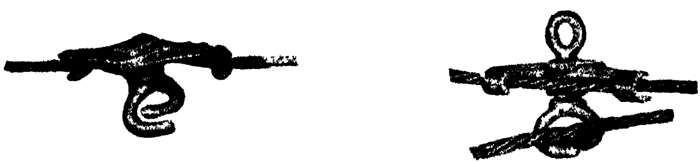
FIGS. 5,934 to 5,936.—*Catenary materials 1.* General Electric insulator pin and insulator. The pin shown in fig. 5,934, is for "T" iron brackets; it can be adjusted along the bracket arm longitudinally. The diameter at the top is 1¼ inch and is suitable for cementing in insulators having 1⅜ inch diameter pin hole. The messenger or pin type insulator figs. 5,935 and 5,936, is adapted for use on voltages up to and including 3,000 volts. It is recommended that insulators be generally purchased assembled on the pins so that purchasers may have the benefit of the high voltage shop test after assembling. When assembling the insulators in the field, the cementing should be done with a good grade of neat Portland

Catenary construction is well adapted to any voltage, but special consideration should be paid to the design of all insulation in anchorage and strains for the higher voltages.

Because of the importance of maintaining the wires in correct location, the tensions in both messenger and trolley are carried higher than in direct suspension systems with the result that all anchorages and strains are under high loading.

For single track lines, wood poles with steel brackets may be used, on double track, cross spans from wood poles with the poles carefully guyed.

For heavy service, the steel bridge or steel poles with cross spans make a more substantial construction and reduce the amount of guying that is found necessary with wood pole construction.



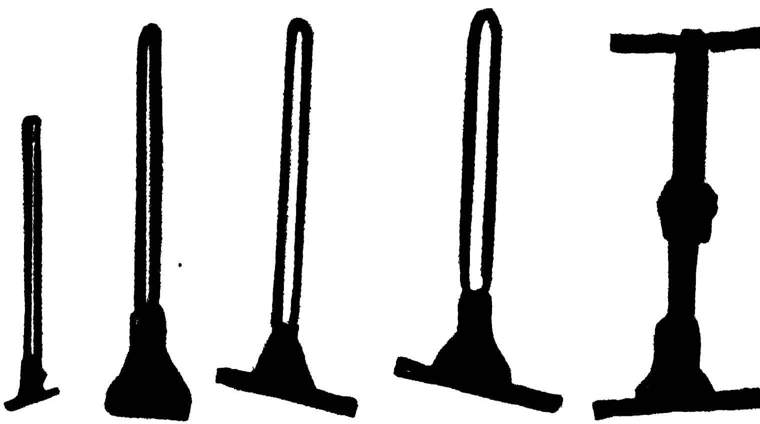
FIGS. 5,937 and 5,938.—*Catenary materials 2.* General Electric span wire messenger supports. They are used for the attachment of the messenger cable to the cross span and are used throughout tangent and curves in cross span construction, except when replaced at anchorages by anchor clamps. The supports are arranged for adjustment to any angle between the messenger and span wires. Fig. 5,937, shows the support which is intended for use in ordinary line construction, and fig. 5,938 a support which is especially adapted for use in yards where many tracks are spanned, the regular cross span wire being picked up at the messenger supports and attached to another cross span wire located above. Both supports are arranged for ⅜ inch span wire and ⅜ inch to ½ inch messenger wire.

With wood pole bracket construction, the messenger must be free to move longitudinally at the insulated support so as to maintain a uniform tension and thus relieve the bracket of strain.

With steel bridge construction, this movement between the insulator and messenger may be prevented and each span designed to take care of its own changes in tension.

Temperature, wind and ice change the tension and sag and must be carefully considered in the design.

The construction must be such that the tension in all wires is below their elastic limit when they are subjected to their maximum wind and ice loading and minimum temperature. It is also important that the stringing of the wires be done in accordance with a temperature tension sag chart, shown in fig. 5,971.



FIGS. 5,939 to 5,943.—*Catenary materials 3.* Various General Electric tangent hangers. The straight line hangers for supporting the trolley wire from the messenger cable are provided with various forms of loops or flexible connections for attaching to the messenger cable, and different forms of mechanical clamping ears for fastening to the trolley wire. The flexible connection or loop hanger for use between messenger and trolley wire permits of a free vertical movement of the trolley wire and hanger from the upward pressure of the collecting device, thus eliminating any pounding or hammer blow directly underneath the hanger and thereby materially increasing the life of the trolley wire itself.

As one of the advantages of catenary construction is the straight trolley without sag, the distance between hangers is important.

Hanger spacings vary from 10 to 50 feet, but it has become common practice to use a nominal spacing of 15 feet for a pantograph or sliding

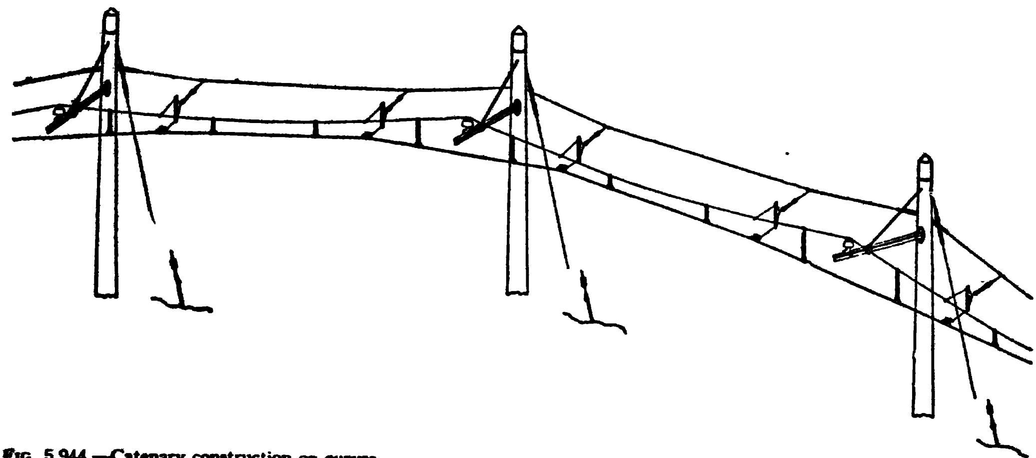


FIG. 5,944.—Catenary construction on curves.

collector and 30 feet for a pole and wheel collector. Especially on electrifications in cities it is often impossible to maintain a standard pole or bridge spacing, in which cases the hanger spacings may only approximate the standard. In a catenary line everything depends upon the messenger, which must never fail. For this reason ordinary steel strand is not recommended.

Siemens-Martin steel is the lowest grade that can be depended upon for the messenger or important anchorages and where loading is high it is better to use high strength or extra high strength.

For ordinary wood pole construction $^{7}/_{16}$ inch extra galvanized strand is generally used, but on long span bridge construction strand as large as $^{5}/_{8}$ inch may be used for the messenger. The correct size to use should be determined by calculation and not assumed from similar practice. For light pull offs and steady strains ½ inch strand is strong enough and is easily worked.

Pole Spacings.—With wood poles, pole spacings as high as 180 feet may be used but 150 feet is common practice for tangents. For steel bridge construction spacings as great as 300 feet, on tangent, are in use.

Curves.—The construction of curves is one that requires considerable study as there are a number of points which must not be overlooked. The trolley is located with respect to the degree of curvature and curve elevation of the track.

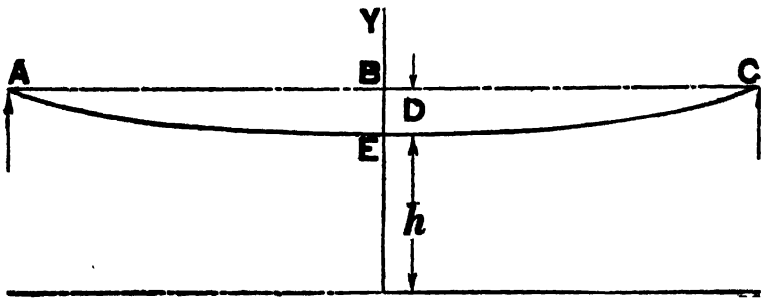


FIG. 5,945.—Catenary curve diagram.

This must be corrected for the side swing of the pantograph or collector and the magnitude of this side swing depends upon the height of the trolley wire and the spring action of the trucks. The transition at the ends of the curve introduces another correction that requires careful treatment. There are curve constructions that can be laid out to produce an ideal condition, but if the construction be not capable of easy adjustment to accommodate track realignment or changes in supporting structures it will develop troubles in operation and high maintenance.

A good curve construction must hold the line in place, but be capable of being easily tuned up and must provide, at all times, a smooth underrun for the collector.

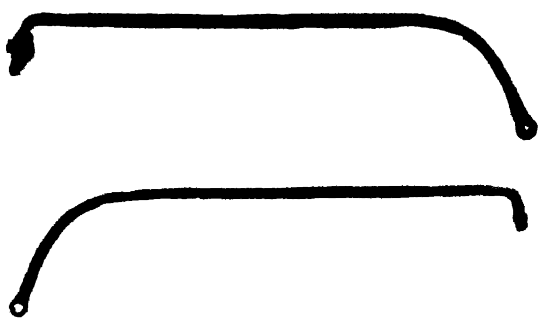
Where pantographs are used, care must be taken to keep all pull-offs clear of the swing of the collector pan or roller. The general practice is to

have a clearance of 6 inches above the trolley wire at a distance of 3 feet on each side.

Where poles are located on the outside of curves having large radii (1 degree or less), a single line steady or pull off, located underneath the bracket, may be used, thus avoiding the expense of erecting a "back bone" construction.

The standard construction for wheel operation consists of an ear, yoke, strain insulator and eye bolt.

Where poles for wheel operation are located on the inside of curves of 1



FIGS. 5,946 and 5,947.—*Catenary materials 4.* General Electric pipe pull offs. In figs. 5,946 the pull off is made of pipe, the ends of which are formed into eyes. One eye is used to attach the pull off wire and the other to bolt on the ear. The distance between the pull off eye and the ear is 3 ft. which provides a clearance of 6 inches for the collectors. The diameter of the eye is ⅝ inch. All parts are sherardized. It is suitable for slider or roller collectors only. The pull off arm, shown in fig. 5,947, is made of pipe, one end of which is formed into an eye and the other into a button head. The eye is used to attach the pull off wire, and a pair of Form L, clamping jaws are attached to the button head for holding the trolley wire. This pull off is 36 ins. long between the center of the eye and trolley wire, and can be used in connection with either slider or wheel collectors. All parts are sherardized. This pull off is generally preferred on account of its light weight.

degree or less, a longer bracket supporting an outer end drop casting should be used together with an ear, yoke, and strain insulator. A 10 ft. arm readily provides clearance and flexibility for this construction on 150 ft. pole spacing on 1 degree curves. On all curves above 2 degrees, the back bone method of construction is recommended for wheel operation. One or more pull offs per span may be used, depending on the radius of the curve. The flexible pull off construction, fig. 5,944, readily permits operating

around curves at the maximum speed permissible for the curve. This construction is preferred where possible.

For wheel operation where poles must be located on the inside of track on curves of more than 1 degree, the back bone method of construction may be supported by outer end drop castings as shown in the illustration. This construction should be limited to 6 degree curves as a maximum, because above this the pole spacing required is necessarily so short that cross span is more economical. The bracket arm should be at least 12 feet long, and some conditions require a 14-foot arm

On long stretches of tangent track, it is often advisable to install line steadiers to prevent a swaying motion which may be set up by the passing collector.

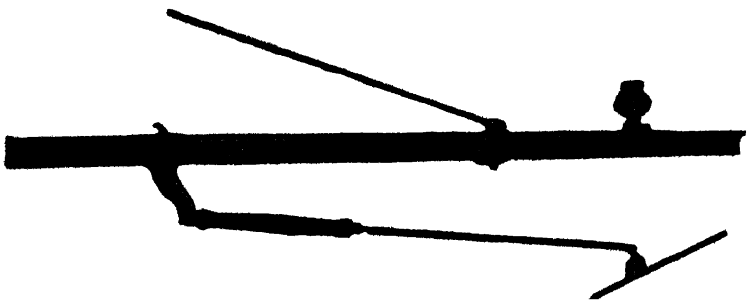


FIG. 5,948.—*Catenary materials 5.* General Electric steady braces. The steady brace for 600 and 1,500 volt lines consists of a malleable iron bracket casting, a wooden body, goose neck rod, and clamping ear. Lateral adjustment is obtained by moving the bracket casting along the bracket arm. It is held in position by a 5/8 in. cup set screw. The brace here shown is suitable for standard sizes of T iron.

For wheel operation, an outer end drop casting supporting an ear, double curve yoke, and strain insulators installed every 600 or 1,000 feet will effectively overcome any tendency in the line to sway.

Catenary Formulæ.—On curves, the distance between messenger supports (pole spacing) is reduced to prevent too great a deflection at the center of the span.

The deflection at the center of the span or at the center between pull-offs can be found from the formula:

$$D = 12\left[R - \sqrt{R^2 - \frac{S^2}{4}}\right]$$

Where

D = Deflection (middle ordinate) at center of span or between pull-offs in *inches*.

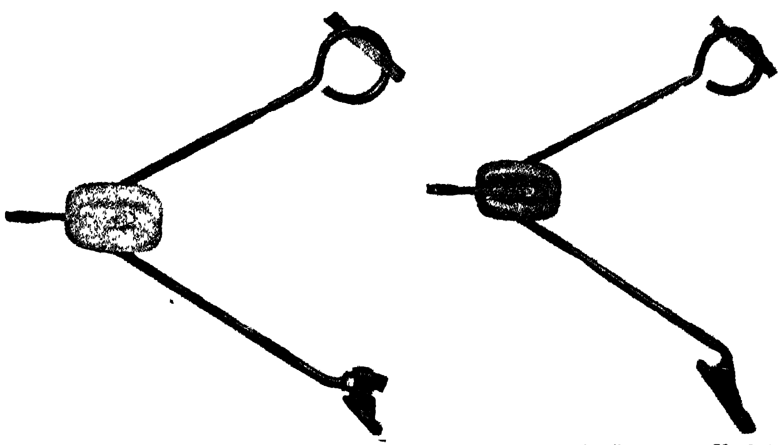
R = Radius of curve in *feet*.

S = Length of span or distance between pull-offs in *feet*.

It is good practice to keep this deflection between pull-offs under 6 inches and the deflection angle for wheel operation under 6°.

In fig. 5,945, the general equation of the catenary AEC, with the origin O, at a distance *h*, below the curve E, is

FIG. 5,949.—*Catenary materials 6.* General Electric butt end trolley wire jointing sleeves.



FIGS. 5,950 and 5,951 —*Catenary materials 7.* Ohio Brass Co. pull off hangers. Used in curve construction where it is necessary to pull messenger and trolley into position. Consists of a ½ in. steel rod shaped as shown. The upper end is formed into a loop which gives a flexible connection with the messenger and the lower end is equipped with a malleable iron clamp which will fit 2-0 to 4-0 grooved trolley wire or an extruded ear which fits 4-0 grooved wire. Rod can be installed in a porcelain strain insulator as shown, before clamp is installed.

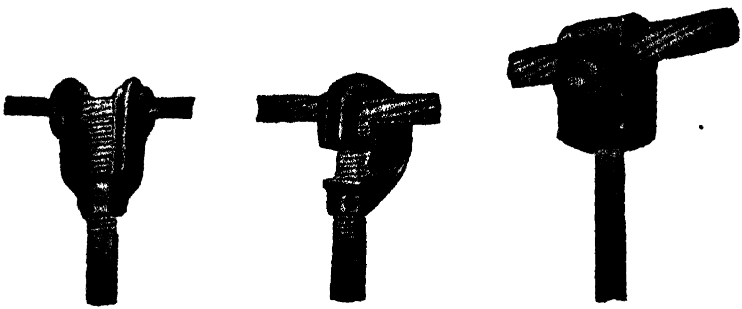
$$y = \frac{h}{2}\left(e^{\frac{x}{h}} + e^{-\frac{x}{h}}\right) \quad \text{(1)}$$

where "e" is the base of the Naperian (hyperbolic) system of logarithms (e = 2.7183). Where the sag is small in proportion to the length ot span, which is usually the case on railway catenary or transmission construction, the curves of a parabola will fill all the conditions of the catenary within practical limits of measurement.

Substituting the parabola formula,

$$y = h + \frac{x^2}{2h} \quad \text{(2)}$$

T = Total tension in wire in *pounds.*



FIGS. 5,952 to 5,954.—*Catenary materials 8.* Various Ohio Brass Co. messenger clips. *They are installed by hooking clip over messenger wire, turning rod until upper end grips* messenger tightly. Used with any ½ or ⅝ in. rod. The clip shown in fig. 5,954 has a concealed nut for threading on to ½ in. rod. Tightened onto messenger wire with bolt.

W = Load in *pounds* per *linear foot* of span (including weight of wire).

S = Length of span in *feet* = ABC.

D = Deflection or sag at center of span in *inches* = BE.

L = Actual length of wire in *feet* = AEC.

$$h = \frac{T}{W} \quad \text{(3)}$$

From (2) and (3) the following useful formulæ are derived:

$$\text{(Pounds)} \quad T = \frac{3}{2}\frac{S^2W}{D} \quad \text{(4)}$$

$$\text{(Inches)} \quad D = \frac{3}{2}\frac{S^2W}{T} \ldots\ldots (5)$$

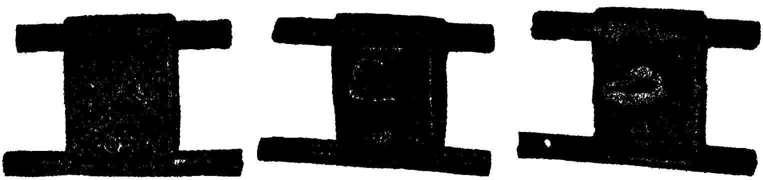
The length of the wire in the span is

$$\text{(Feet)} \quad L = S + \frac{D^2}{54S} \ldots\ldots (6)$$

$$\text{(Inches)} \quad D = \sqrt{54S(L-S)} \ldots\ldots (7)$$

The length of hangers is $y-h+6$. Where 6 is the distance in inches the trolley wire hangs below the lowest point of the messenger, E. Six inches is the generally accepted standard but may be changed if desired.

$$\text{Hanger length in inches} = \frac{6x^2W}{T} + 6 \ldots\ldots (8)$$

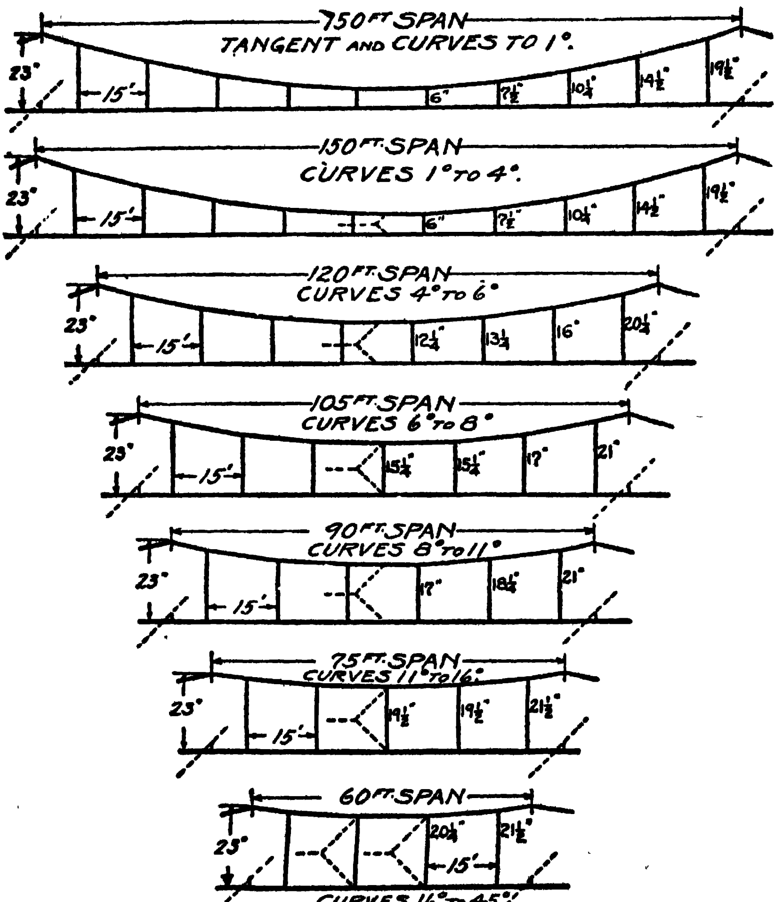


FIGS. 5,955 to 5,957.—*Catenary materials 9.* Various Ohio Brass Co. duplex clamps. They are used where it is desired to install two trolley wires—a steel contact wire because of its wearing qualities and a copper wire for feeder, the latter being supported from a messenger in the same manner as when single catenary construction is used. Installed midway between regular catenary hangers, thus providing greater flexibility. Clamps completely encircle upper wire but allow longitudinal movement.

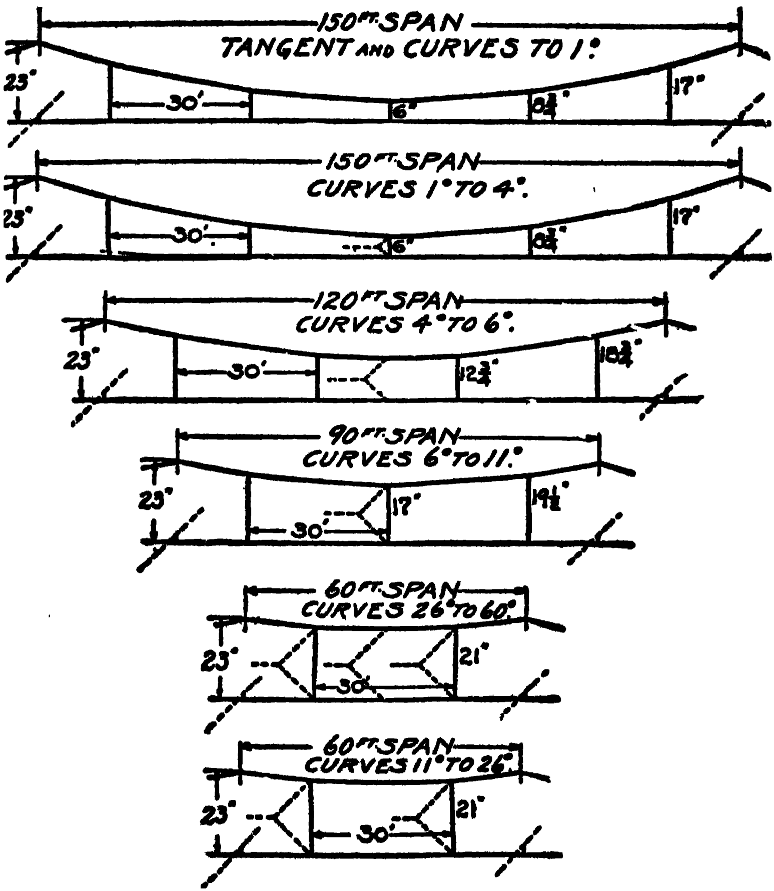
where x, is the distance (feet) from the center of the span to the hanger in question. Hanger length is measured from center of messenger to center of trolley wire.

Sag in Spans.—The curves fig. 5,971 show the relation of tension to sag for the spans shown in figs. 5,958 to 5,970 and also show the effect of temperature changes. *These sag curves are plotted from the formula*

$$T = \frac{3}{2}\frac{S^2W}{D}$$



FIGS. 5,958 to 5,964.—Hanger lengths for 150 ft. pole spacing on tangents and proper shorter spacings and pull off locations for curves. Hangers spaced 15 ft. for pantograph or wheel collector. The curves figs. 5,971 and 5,972 are calculated for these spans.



FIGS. 5,965 to 5,970.—Hanger lengths for 150 ft. pole spacing on tangents and proper shorter spacings and pull off locations for curves. Hangers spaced 30 ft. for wheel collector. The curves figs. 5,971 and 5,972 are calculated for these spans.

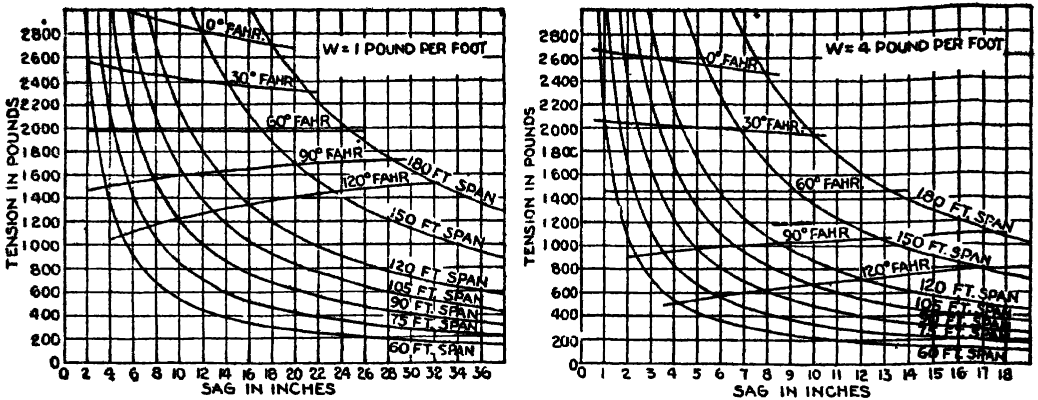


FIG. 5,971 and 5,972.—Tensions and sags for 7/16 messenger. Fig. 5,971 loaded messenger; fig. 5,972 unloaded messenger.

W, is taken at 1 pound per foot and the temperature curves are calculated for a 7/16 inch steel messenger having a cross section of .1188 sq. in. and a modulus of elasticity of 22,000,000. For other conditions it is necessary to plot other curves.

The curves in fig. 5,971 are all calculated for the same tension at 60° which gives the sags and hanger lengths as shown in figs. 5,958 to 5,970. It is obvious that all the spans in a given line must have the same tension when at the same temperature; otherwise each span would have to be anchored.

The temperature curves show that if the trolley wire be a straight line at 60° it will be curved upward when the temperature falls and sag down when the temperature rises. The changed tensions and sags are shown at the intersections of the temperature and sag curves. These curves are calculated from constants and in practice the results will vary from the calculated quantities.

Messenger strand should always be pulled up to the approximate working tension and be permitted to take its initial set before anchoring it for the required sag. Variations in tension and sag due to temperature changes may not be as

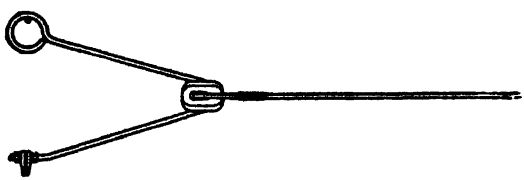


FIG. 5,973.—Ohio Brass pull off hanger for wheel or pantograph.

great as shown in the curves because of the flexibility of poles and anchorages, but when poles and anchorages are rigid the changes shown will take place.

The curves in fig. 5,972 show the sags and temperature changes for the same 7/16 in. steel messenger and spans as in fig. 5,971, except that the messenger is unloaded. Fig. 5,972 is useful in erecting the line as it shows the tension and sag to pull the messenger to before suspending the trolley wire and hangers. After the trolley wire is suspended the conditions are as shown in fig. 5,971.

Ice and Wind Loads.—In figuring ice and wind loads it is customary to assume an ice coating ½ inch in thickness and

a wind pressure on the ice coated wire of 8 pounds per sq. ft. of projected surface. The weight of ice is figured at .033 lbs. per cu. in

For districts not affected with sleet formation a maximum wind pressure of 30 lbs. per sq. ft. of projected surface is frequently used as the limiting condition. In all cases find minimum and maximum temperature from the Weather Bureau. The Bureau of Standards issues publications dealing with the loading of wires.

Figs. 5,974 and 5,975.—Ohio Brass catenary messenger splicer and dead end. Fig. 5,974, cable splicer; fig. 5,975, dead end.

Fig. 5.976.—Ohio brass catenary messenger cable dead end or strain insulator.

TEST QUESTIONS

1. *From what does the catenary system derive its name?*
2. *Describe a simple catenary system.*
3. *For what conditions is the catenary system well adapted?*
4. *Draw a sketch showing span anchor construction for pantograph collector.*
5. *How are connecting links installed for turnouts and crossings?*
6. *What is a pull off spreader?*
7. *Describe a flexible pull over for pantograph.*
8. *Draw a sketch of catenary cross bands for single track.*
9. *What is a duplex catenary?*
10. *Draw a sketch showing method of installing catenary section insulators.*
11. *Describe the method of supporting the trolley or slipper wire.*
12. *What is a compound catenary?*
13. *Is catenary construction well adapted to any voltage?*
14. *What kind of poles may be used for single track lines?*
15. *What kind of supporting structure should be used for heavy service?*
16. *Why is the distance between hangers important?*
17. *What spacing should be given to poles?*
18. *Describe the catenary construction on curves.*
19. *What is the requirement for a good curve construction?*
20. *What precaution must be taken where pantographs are used?*

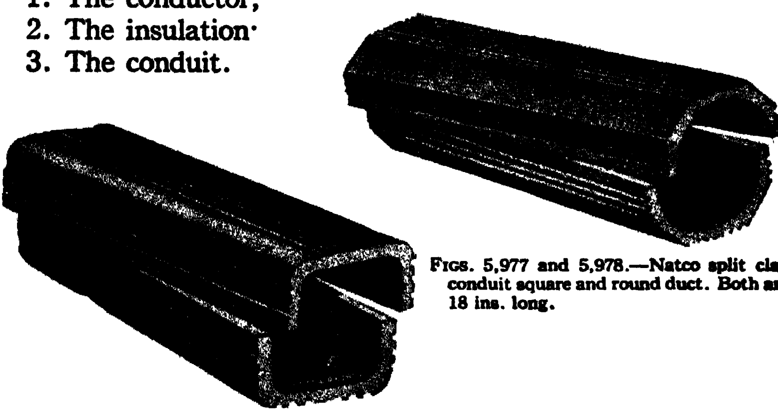
21. *What should be provided on long stretches of tangent track?*
22. *Describe the construction of steady braces.*
23. *Give the various formulæ used in the design of catenary systems.*

CHAPTER 122

Wiring Underground

An underground system of electrical conductors is composed of three essential elements:

1. The conductor;
2. The insulation·
3. The conduit.



Figs. 5,977 and 5,978.—Natco split clay conduit square and round duct. Both are 18 ins. long.

The various underground systems may be divided into three classes:

1. Lead encased cables laid directly in the ground;
2. Solid or built in systems;
3. Drawing in systems.

Where cables are laid directly in the ground, the metallic covering, consisting usually of a lead tube which is placed over the insulation is depended upon for mechanical protection.

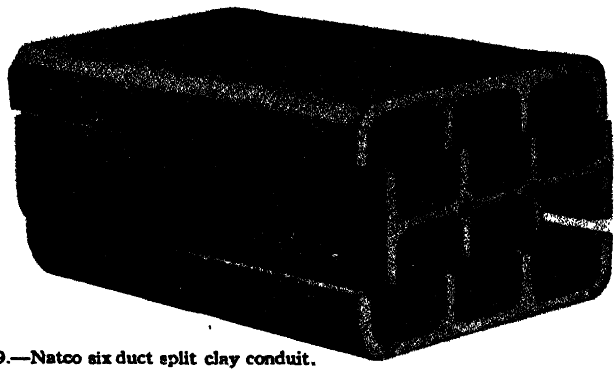
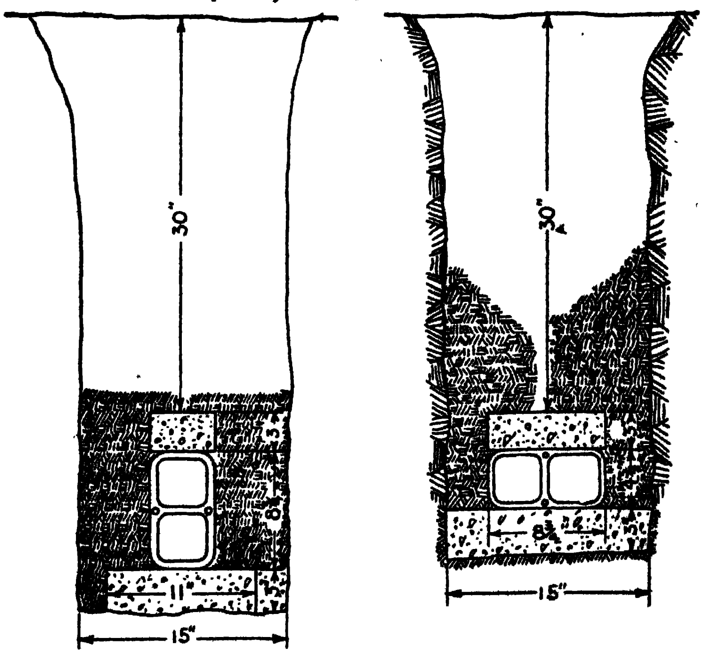


FIG. 5,979.—Natco six duct split clay conduit.



FIGS. 5,980 and 5,981.—Typical bank formations Natco multiple duct clay conduit. Fig 5,980, 2 ducts, 3¼ in. bore, 1 wide formation; fig. 5,981, 2 ducts, 3¼ in. bore, 2 wide formation.

Such cables are largely used for short private lines and the first cost is less than that of the others, but in case of repairs they have to be dug up.

The conduit of the solid or built in systems consists of steel pipe or concrete trenches, and that of the drawing in system consists of various forms of pipe or troughs of iron, earthenware, concrete, wood or fibre, etc.

Conduits.—There are numerous kinds of conduits, and they may be classified with respect to material, as

1. Vitrified clay;
2. Wood;
3. Fibre;
4. Metallic.

Vitrified Clay Conduit. — By definition, *vitrified clay* is a *clay which has been subjected to intense heat so as to receive a glassy surface which renders it proof against chemical action.*

FIG. 5,982.—Natco 2 duct transposition conduit; typical assembly. 90° combination *l.h* and *r.h* assembly. Total length 16 ft. Another use of this shape is to provide a 180° assembly either *r.h.* or *l.h.* in a distance of 16 ft. for the purpose of reversing the position of top and bottom cables.

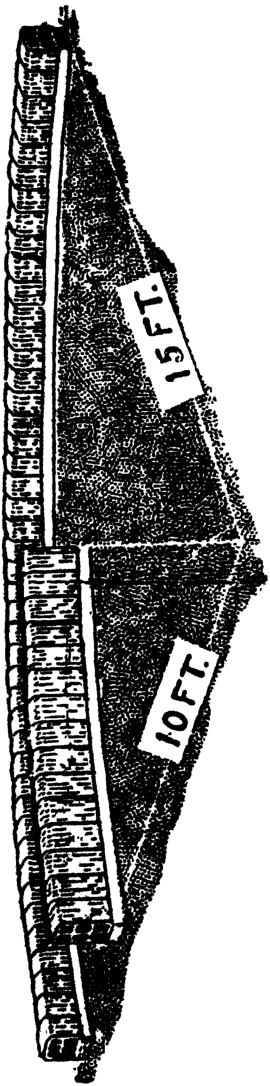


FIG. 5,983.—Assembly of Natco slant (or mitered) conduit for building curves. The illustration shows: 6 way edge position 45°, 10 ft. radius; also, 6 way flat position 90°, 15 ft. radius.

It has very high insulating properties which make it very valuable for conduits in underground wiring, being at the same time inexpensive and easily laid.

The conduits are made in both single and multiple duct, the single type being about 3½ inches in diameter, or 3½ inches square, and 18 inches long. Multiple conduit is made in two, three, four, six and nine sections, ranging from 2 to 3 feet in length.

Single conduit is best suited where there is great crowding of gas, water and other pipes, as the conduit can be divided into several layers so as to cross over or under such pipes.

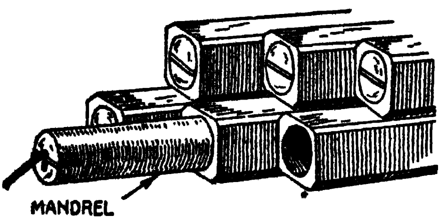
The multi-duct conduit can be laid somewhat cheaper, especially in lines of about two to four ducts; it is best suited to districts free from subsurface obstructions.

Laying Vitrified Clay Pipe Conduit.—In laying the conduit a trench is dug, usually sufficiently wide to allow the placing of three inches of concrete on each side of the ducts, and sufficiently deep to hold at least thirty inches of concrete on top

of the upper layer of concrete forming the conduit, and to allow for three inches of concrete in the bottom.

The trench is graded from some point near the middle of the block to the manhole at each intersection, or from one manhole to the next manhole, at a gradient not less than 2 inches to 100 feet.

The tiles of the several ducts are placed close together, and the joints plastered and filled with cement mortar consisting of one part of Portland cement to one part of sand. When the conduit is being laid, a wooden mandrel about four or five feet long, three inches in diameter, and carrying at one end a leather or rubber washer from three to eight inches larger



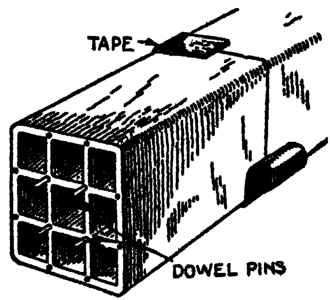


FIG. 5,984.—Method of laying single duct vitrified clay conduit. The tiles of the several ducts are placed close together as shown in the figure, and the joints plastered and filled with cement mortar consisting of one part Portland cement and one part sand.

FIG. 5,985.—Method of laying multiple duct vitrified clay conduit. The sections are centered by the dowel pins shown in the cut.

is drawn through each duct so as to draw out any particles of foreign matter or cement which may have become lodged in the joints, and also to insure good alignment of the tiles.

Single duct conduits are usually laid by bricklayers. This fact accounts for the somewhat greater cost of the single over the multiple conduit which is usually laid by ordinary laborers. One good brick layer and helper, however, will lay from 200 to 300 feet of single duct conduit per hour.

Vitrified Clay Trough Conduit.—It consists of troughs either simple or with partitions as shown in fig. 5,986.

They are usually made in tiles 3 or 4 inches square for each compartment, with walls about one inch thick. The length of the tiles ranges from two to four feet. Each of the two foot form duct troughs weighs about 85 pounds. When laid complete, the top trough is covered with a sheet of mild steel, about No. 22 gauge, made to fit over the sides so as to hold it in position, and then covered over with concrete.

Laying Trough Conduit.—In laying multiple duct earthenware conduit, the ducts or sections are centered by means of dowel pins inserted in the holes at each joint, which is then wrapped with a six inch strip of asphalted burlap, or damp cheese cloth, and coated with cement mortar as shown in fig.

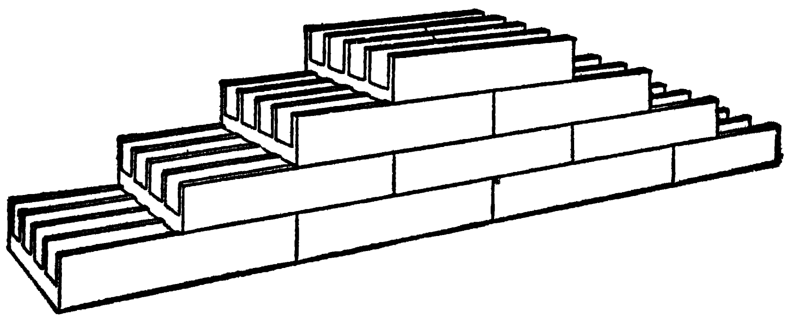


FIG. 5,986.—Vitrified clay or earthenware trough conduit; this type of conduit consists of troughs either simple or with partitions, the latter type being shown in the figure.

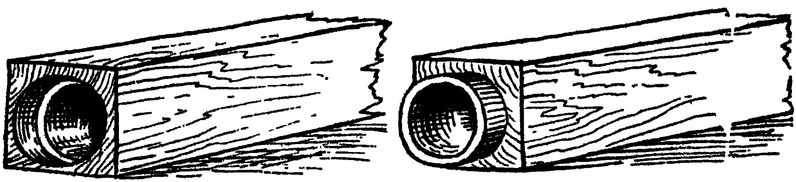
5,985. Economy of space and labor constitutes the principal advantages derived from the use of multiple duct conduit.

Concrete Conduits.—These are usually constructed by placing collapsible mandrels of wood or metal in a trench where the ducts are desired and then filling the trench with concrete.

After the concrete has solidified, the mandrels are taken out in pieces, leaving continuous longitudinal holes which serve as ducts. Some builders produce a similar result by placing tubes of sheet iron or zinc in the concrete

as it is being filled into the trench. These tubes have just enough strength to withstand the pressure to which they are subjected, and are, therefore, very thin and liable to be quickly destroyed by corrosion, but the ducts formed by them will always remain unimpaired in the hardened mass of concrete.

Wooden Conduits.—In this type of conduit, the ducts are formed of wooden pipe, troughing or boxes, and constitute the simplest and cheapest form of conduit.



FIGS. 5,987 and 5,988.—Wooden pipe type of conduit showing female and male ends.

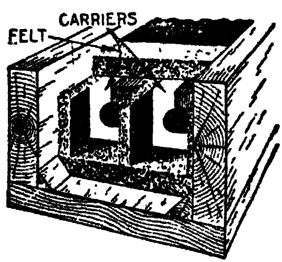


FIG. 5,989.—Perspective view of wooden built-in conduit. *It consists of* an outer rectangular casing of wood which is lined inside with impregnated felt. *In construction,* a wooden trough is laid in a trench about 18 inches deep. Porcelain carriers are placed in the trough at intervals of 4 to 5 feet, to act as bridgework for supporting the conductors. This bridgework is placed on and is surrounded by impregnated felt or similar material, and the spaces between the carriers, after the conductors have been placed in position on them is filled with voltax, which hardens rapidly and forms a solid insulating material throughout the conduit.

A pipe conduit consists of pieces of wood about 4½ inches square, and three to six feet long, with a round hole about three inches in diameter bored through them longitudinally. As shown by fig. 5,988 a cylindrical

projection is turned on one end of each section, which, when the conduit is laid fits into a corresponding recess in one end of the next section. The sec tions are usually laid in tiers, those of one tier breaking joint with those of the tiers above or below.

The trough conduit consists of ducts about 3 inches square made of horizontal boards and vertical partitions, usually of yellow pine about one inch in thickness. This form of conduit can be laid in lengths of 10 and 12 ft., or it can be built along continuously. The life of wooden conduit may be increased by the application of sterilizing processes.

Wrought Iron or Steel Conduits.—These are formed of

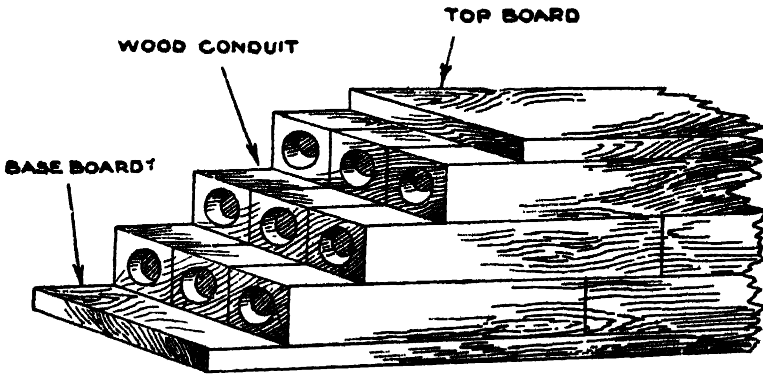


FIG. 5,990.—Wyckoff multi-duct creosoted wooden conduit showing top and base board. Each piece registers with the adjoining piece, by means of the mortise and tenon joint without the use of mandrels, or other means to make the alignment of adjacent pieces perfect.

pipes similar to gas or steam pipes, with screw or other connections.

They are laid either simply in the earth, or in hydraulic cement, and are the strongest and one of the most satisfactory forms of underground conduit. In construction, a trench, the width of which will depend upon the number of pipes to be laid, is first dug in the ground, and after its bottom has been carefully leveled, is braced with side planking and filled to the depth of two to four inches with a layer of good concrete, consisting of two parts of Rosendale cement, three parts of sand, and five parts of broken stone capable of passing through a one and one-half inch mesh.

This concrete is well secured in place and forms the bed for the lowermost layer or tier of pipes.

Ordinary wrought steel or preferably wrought iron pipe is employed, in 20 foot lengths about three to four inches in diameter, depending upon the size and number of cables they are intended to carry. After the last tier of pipes has been put in place, and a layer of concrete from two to four inches placed over it, a layer of two inch yellow pine planking is laid over the whole.

The principal object of the top covering is to protect the conduit against the tools of workmen making later excavations.

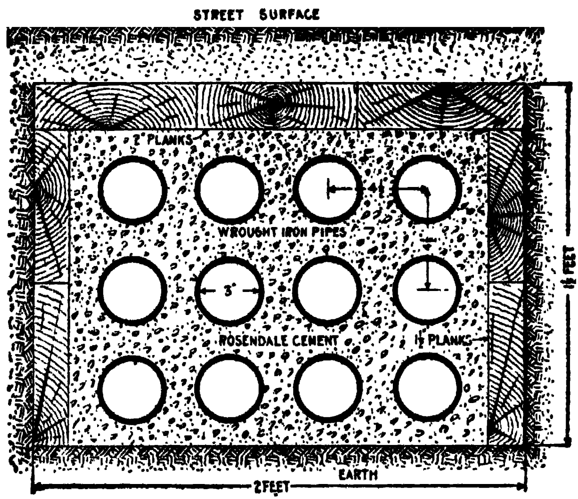


FIG. 5,991.—Cross section of wrought iron pipe conduit laid in hydraulic cement.

Practical experience shows that workmen will dig through concrete without stopping to investigate as to the character of the obstruction, but under similar circumstances, will invariably turn away from wood.

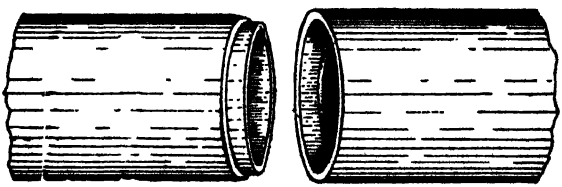
In best construction the pipes are lined with a layer of cement ⅝ in. thick and containing no sand.

Cast Iron Conduit.—Cast iron pipe for underground conduits is similar to ordinary wrought iron pipe, except that it is thicker.

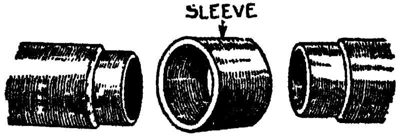
The additional thickness is necessary to mal·: the strength equal to that of wrought iron; it is therefore heavier to handle and more expensive.

The trough conduit consists of shallow troughs of cast iron in six foot lengths, laid directly in the earth so as to form a system of continuous troughing in which the conductors are placed and then covered over by cast iron covers which are bolted to the trough.

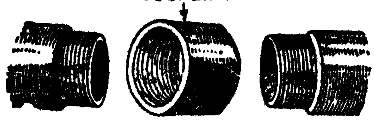
The advantages are that the cables can be laid directly in place, thus eliminating any chance of injury during the process of drawing in, and second, the cables are easily accessible at any point by simply removing one or two of the sectional cast iron covers, thus permitting of their being readily inspected and repaired.



FIGS. 5,992 and 5,993.—Fibre conduit socket joint. The joint is cut to a slight taper, uniform in size and reamed so that there is no appreciable offset on the inside of the pipe at the joints. Since these joints are machine cut, they form a connection that is perfect in fit and alignment. The socket joint, while not offering all the advantages of the tapered sleeve, gives satisfactory results for underground conduit systems when laid in concrete.



FIGS. 5,994 to 5,996.—Sleeve joint type of fibre conduit. Both the socket type and the sleeve type here shown are easily aligned without the use of a mandrel.



FIGS. 5,997 to 5,999.—Screw joint type of fibre conduit. This method of connection will form a tight line and is suitable for running under the lawns of private houses and parks, under the streets of towns and villages, and in other places where the cost of building electric subways is prohibitive.

Fibre Conduits.—This form of conduit consists of pipes made of wood pulp impregnated with a bituminous preservative and insulating compound.

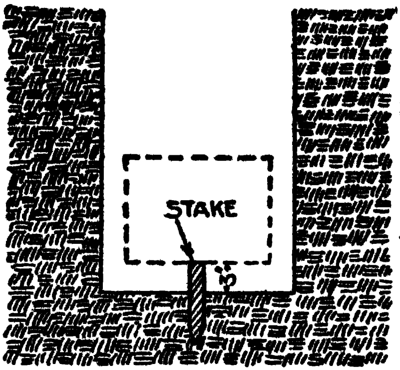
Three types of joint are available for connecting lengths of fibre conduit.

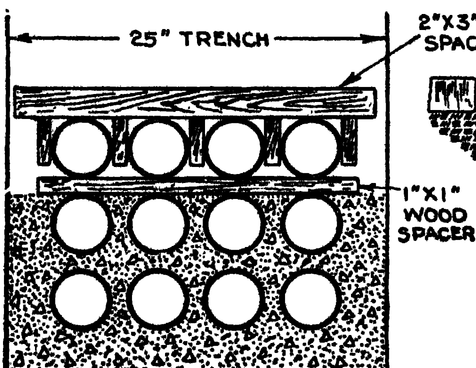
1. Socket joint;
2. Tapered sleeve joint;
3. Screw joint.

These various types of joints are shown in figs. 5,992 to 5,999.

Installation of Fibre Conduit.—There are two methods of installing fibre conduit.

1. Tier by tier method;
2. Built up method.





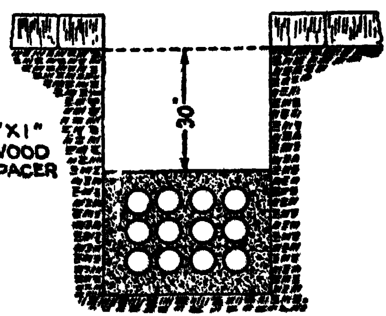


FIG. 6,000.—Conduit excavation showing grade stake.

FIG. 6,001.—Installation of fibre conduit showing spacers which are removed when tiers is partly concreted.

FIG. 6,002.—Conduit installation ready for backfill

Tier by Tier Method.—This consists of placing on the bed of the trench a foundation of concrete, laying thereon the lowest tier of ducts, holding them at the desired horizontal separation, filling the spaces between the ducts with the concrete and spreading concrete over them until the desired vertical separation has been obtained. The operation is repeated tier by tier until the required number of ducts has been laid.

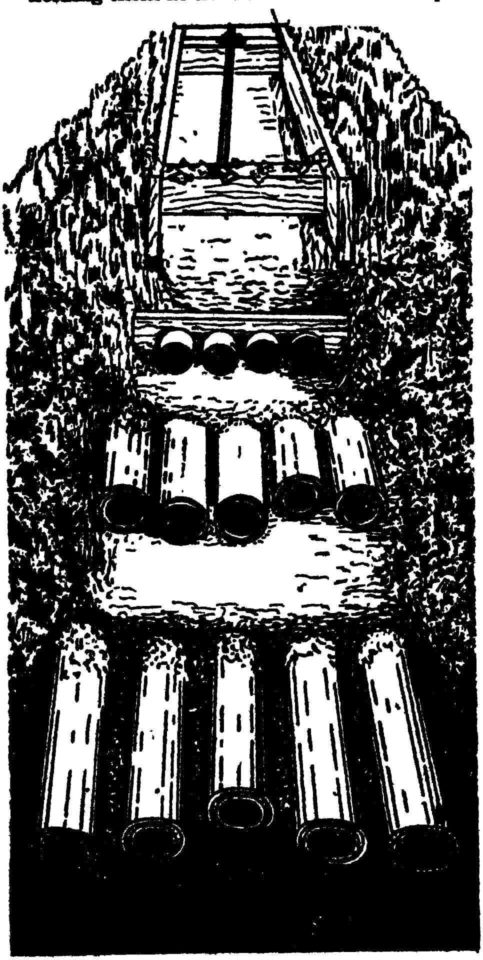


FIG. 6,003.—Tier by tier method of laying fibre conduit showing installation of 14 single duct conduits.

The concrete base for the conduit should be laid only on firm dirt carefully tamped. This base is usually made 3 ins. thick, the proper depth being insured by stakes driven at intervals into the bottom of the trench and extending 3 ins. above the grade. A space 3 ins. wide between the duct rows and each side of the trench is also filled with concrete and the top tier finally likewise covered.

The several tiers are separated vertically and horizontally by concrete varying from 1 in. to 3 ins. according to voltage to be carried, amount of ventilation in the ducts and the personal conviction of the engineers.

Upon the concrete foundation the first row of conduits is laid, these being properly spaced by means of wooden or concrete combs, as shown in fig. 6,001, placed at approximately 3 ft. intervals. Concrete is

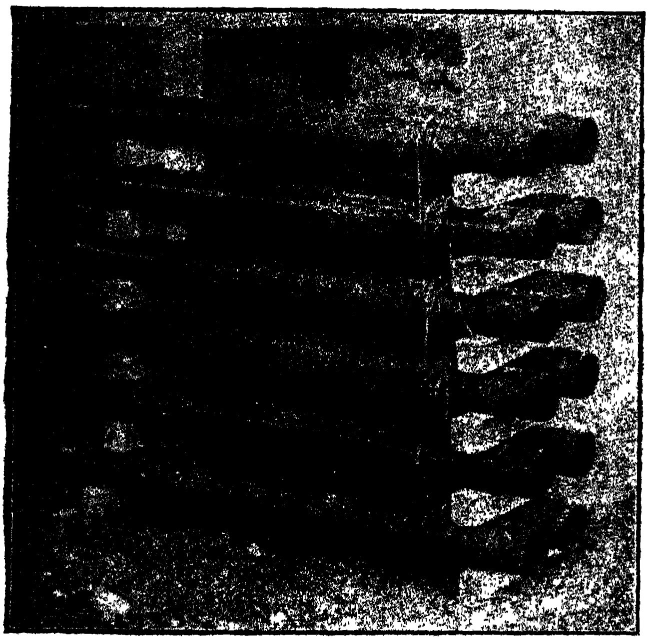


FIG. 6,004.—Orangeburg fibre conduit showing method of tying when using rectangular separators previous to installing by the built up method.

then poured until the tier of ducts is covered to the desired depth and tamped level, a spacing comb at the unfinished end of the line being left in place to indicate accurately the thickness of the concrete. If of wood, the comb is then removed. The desired duct section is thus formed in successive tiers.

Good engineering practice calls for staggering the joints in adjacent

pipes and for making all joints perfectly tight to prevent concrete entering and blocking the ducts. Generally a 1-3-5 mixture is used consisting of one part of cement, three parts of sand and five parts of stone broken fine enough to pass a ¾ in. mesh sieve. The amount of water should be carefully watched so the concrete is just thin enough to be easily tamped around the

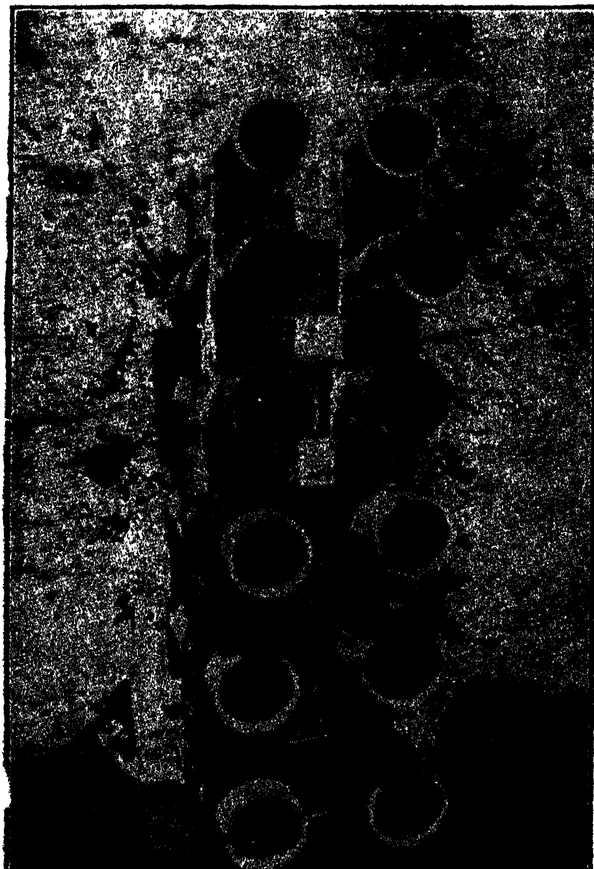


FIG. 6,005.—Built up installation of Orangeburg conduit using rectangular separators.

ducts with no superfluous moisture. The advantages claimed for this method by many engineers is the certainty that the separations between the several tiers of duct will be perfect.

As only a few inches thickness of concrete is spread at any one time, thorough tamping around each duct is readily accomplished and the possibility of voids eliminated.

Built up Method.—With this method the several tiers of duct are all placed in position one above the other before any concrete is poured. The

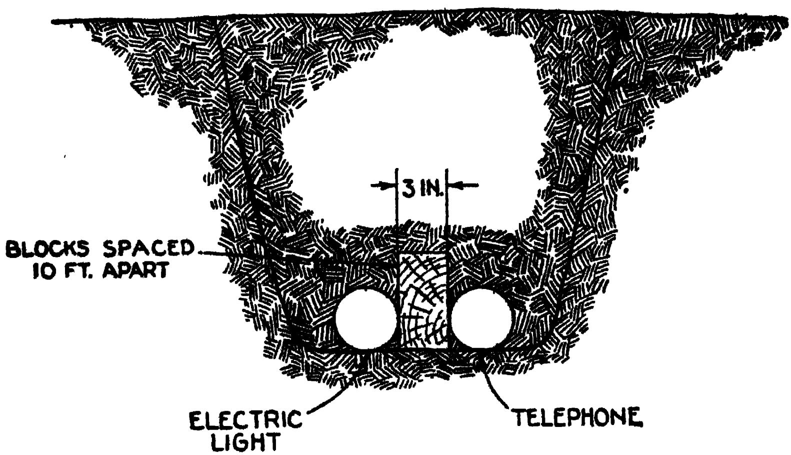


FIG. 6,006.—Telephone and electric light in same trench. Where the duct provided for electric service will be occupied by secondary circuits only which are connected to transformers not exceeding 25 *kw*. capacity, the clearance between telephone and electric light ducts must be not less than 3 ins. provided that stakes, spacers, bricks or paving blocks are placed every 10 ft. to make certain that this separation is maintained.

ducts are held in proper position by concrete separators which later become permanently inbedded in the concrete mass. These separators are of different design. Some engineers use rectangular forms of proper width placing them both vertically and horizontally at sufficient intervals to support the ducts rigidly.

To prevent all possibility of the ducts floating when the concrete is poured they are also bound together by tying them in groups of four with hemp twine. This must be done carefully in order to have the conduit runs perfectly in alignment when the work is completed.

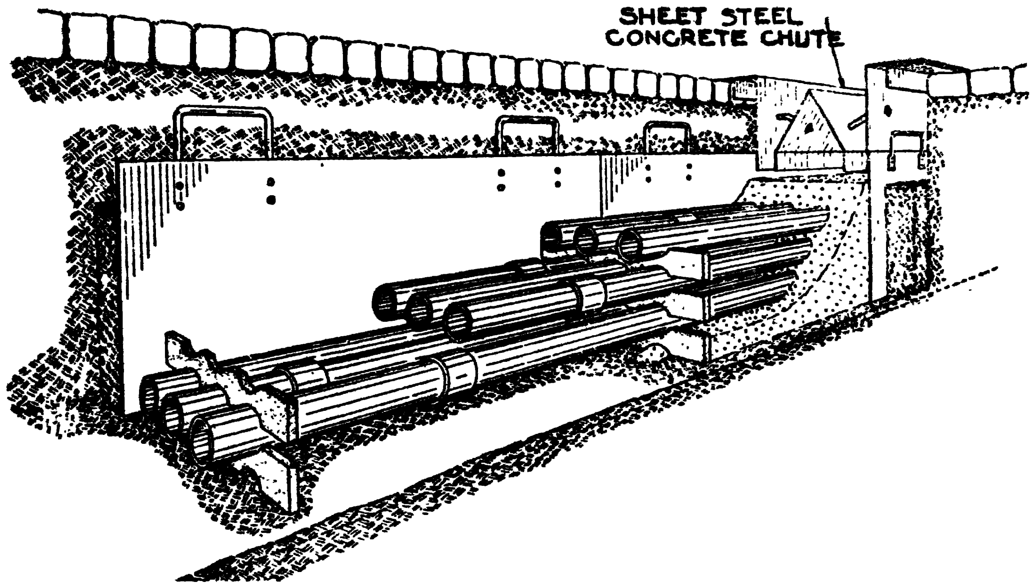
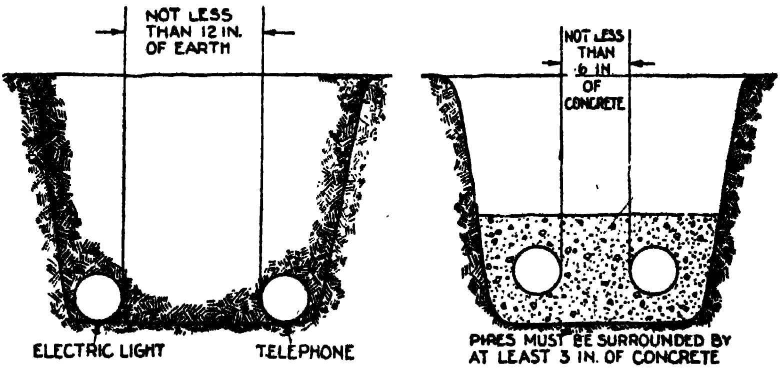


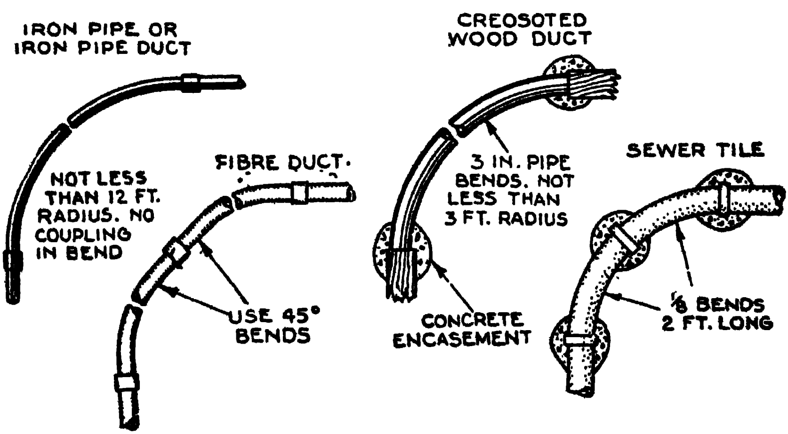
FIG. 6,007.—Built up method of installing fibre conduit using grooved separators.

Other engineers use concrete forms as shown in fig. 6,007. The outline of these is made to follow the curve of the fibre which is laid in the upper curved grooves of the separators and held in place by the lower grooves of the one on top. Sand bags or bars of iron are then placed on top of the upper tier of ducts to prevent any movement of the conduit when the concrete is poured. All the joints in the several duct runs should be staggered.

When all the tiers are in position, concrete is poured or shovelled into the trench, care being taken to see that it is dropped slowly enough to prevent damage to the ducts. In a deep trench such damage is obviated by



Figs. 6,008 and 6,009.—Separation of telephone and electric light conduits where the duct provided for electric service is, or may be occupied by secondary circuits connected to transformers of over 25 *kw*. capacity or by primary circuits of any capacity. These clearances apply likewise at crossings of one service over the other.



Figs. 6.010 to 6,013.—Bends in run of various types of conduit.

pouring upon a board laid over the ducts. The concrete is then shovelled from this board in small lots and tamped in final position under and alongside the various tiers. On long runs where conditions warrant it, better results are obtained by the use of a deflecting trough of steel, the concrete flowing from each side of the trench toward the middle, and if of the proper consistency entirely filling all voids under and around the ducts.

A 1-3-5 concrete mixture is used, as in the tier by tier method. Many engineers prefer this method since by pouring the concrete as a whole a monolithic form of duct separation is obtained, making it impossible for horizontal joints to exist between different layers of concrete.

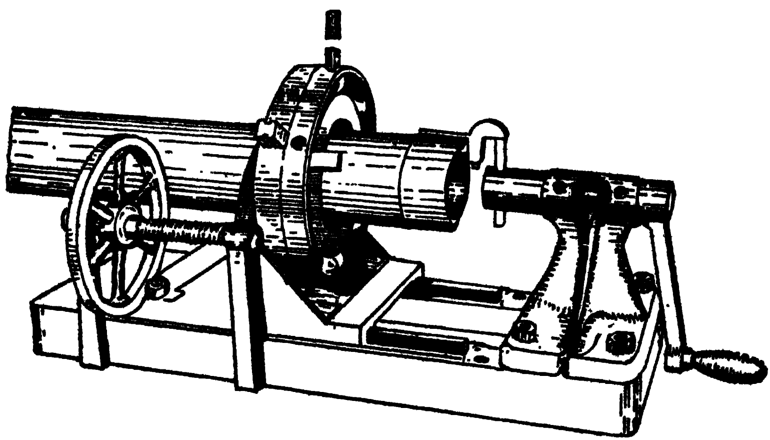


FIG. 6,014.—Johns-Manville portable machine for cutting joints. Where large quantities of conduit are used, short lengths are frequently necessary and are obtained in the field by cutting down regular sections, with a machine such as here illustrated. The use of these lathes prevents loss of conduit by providing a quick and accurate means of re-tooling such ends as may have become broken in handling.

Conduit Boxes or Manholes.—*By definition a manhole is a vault or box-like structure built under the street, having a circular opening at the street surface covered by a cast iron cover, and large enough to conveniently admit a man, so that access may be had to the conduit ducts and the cables.*

Manholes should be provided about every 300 feet, in order to facilitate the installation of the conductors in the duct.

The exact distance between manholes should be determined by conditions; in some cases they should be placed even closer together than the figure given, while in other cases their distance apart might be slightly greater. Manholes are built of concrete or brick, and provided with a cast-iron frame or cover. The manholes may be of square, round, rectangular, or oval section, the last mentioned form of manhole being probably the best, as it avoids the liability to sharp bends or kinks being made in the cable.

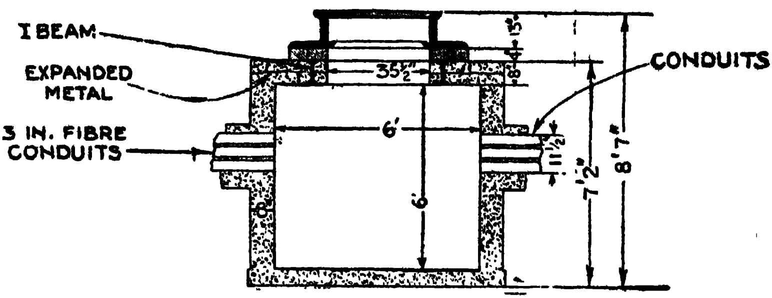
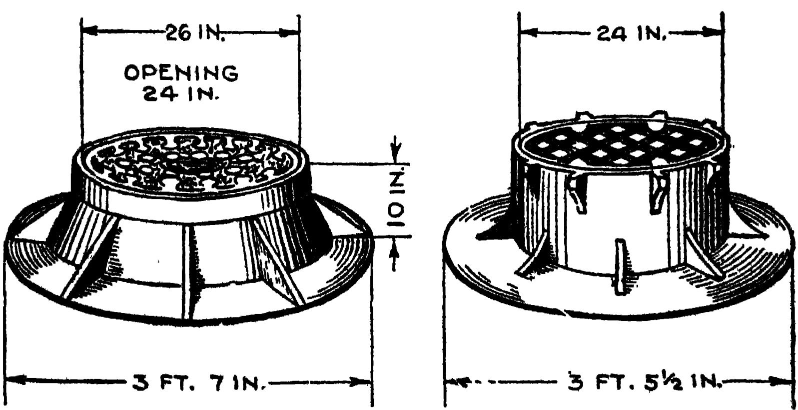


FIG. 6,015.—Standard form of manhole used in New York City.



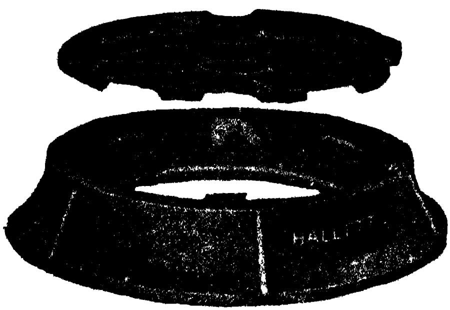
FIGS. 6,016 and 6,017.—Telephone and sewer types of manhole frame and cover. Either type may be used.

The manhole cover may be of the same form as the manhole itself, or it may be of different form; but round or square covers are usually used

Fig. 6,015 shows a standard form of manhole used in New York City This manhole is substantially built, and adapted for heavy traffic passing over the cover. For suburban or country work, manholes may be made of lighter construction. In all cases the cover should be readily removable.

The floor of the conduit boxes must be of earth to allow drainage. If paving be desired, the floor should be made of brick or cobble stones laid loosely on the earth without mortar joints.

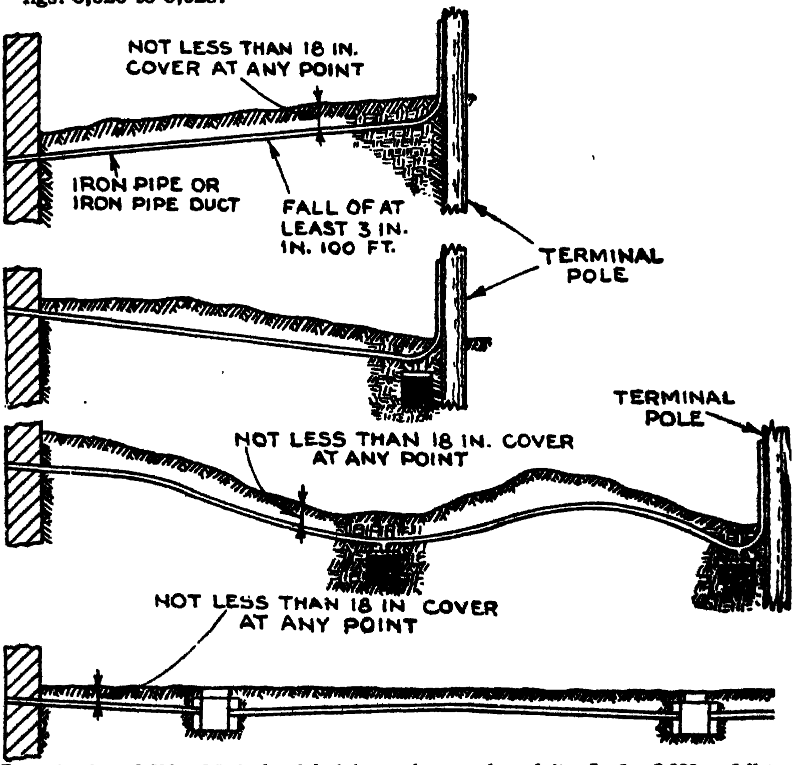
Electric light or power wires and telephone wires must not occupy the same conduit box. Separate conduit boxes may be built with one wall common to both, but each conduit box should have a separate entrance and there must be no opening between the two boxes.



Figs. 6,018 and 6,019.—D & D manhole cover. The cover does not rest on top of the lugs, but on the 45° angle side of the lugs and is held in place by the 85° side. The cover is opened by using two short bars which can be operated by one man by simply prying first on one bar and then reversely on the other until the cover leaves its seat and can then be carried off without any trouble. Another method is to insert a large cold chisel in the keyhole of the cover, and strike it a few heavy blows with a hammer which will loosen the cover in a few minutes even in below zero weather.

Drainage.—Water will gradually accumulate in the conduit unless good drainage be provided. If drainage be not provided, and water accumulates in the duct, the water may freeze in winter in territories subject to low temperatures and damage the cable to such an extent that a complete failure of the cable will result. In addition to loss of service the replacing of the cable may be expensive because of the difficulty of thawing the pipe in order to remove the damaged cable and place the new one.

It may be found necessary to place a conduit box or a drainage pocket at a point where, either on account of the nature of the soil or because of the contour of the ground, water accumulating in the conduit box or pocket will not drain easily. Drainage pockets are unnecessary in districts where freezing at conduit depth will not occur. Methods of drainage are shown in figs. 6,020 to 6,023.



FIGS. 6,020 to 6,023.—Methods of draining underground conduit. In fig. 6,020, a fall toward the house should be provided only where iron pipe or iron pipe duct is used and no conduit box is built in the run. Otherwise, the fall should be toward the pole or conduit box. In fig. 6,021, where fall is toward the pole a drainage pocket must be provided. In fig. 6,022, where it is impracticable to grade trench so that it makes a continuous fall, a drainage pocket must be provided at lowest point in the dip. Fig. 6,023 shows fall of 3 ins. in 100 ft. toward conduit box. The fall must not be toward house where conduit runs to conduit box. Fall of 3 ins. in 100 ft. toward one conduit box or both. A continuous fall toward one conduit box is preferable where the slope of the ground permits.

Pulling in the Cables.—In this operation special precaution should be taken to avoid sharp bending of the cable and thus prevent injury to the lead sheathing. If the cable be light and of small diameter, the distance not over 300 feet, and the run fairly straight, the cable can usually be pulled in by hand; but often other means must be provided so as to secure sufficient power.

FIGS. 6,024 and 6,025.—Hallett manhole skids and sheaves. *These are for* leading the pulling line from the mouth of duct out through the manhole to the capstan or winch. The skids have pinholes every 4 ins. from top to bottom so that sheaves can be placed at desired height to correspond to height of duct and top of manhole. They are made of channel iron, and are suitable for pulling in the heaviest cables. Standard length, 9 ft.

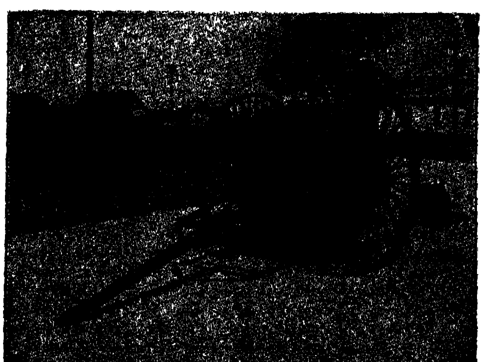


FIG. 6,026.—Hallett cable reel wheels. This outfit is used on cable reels of whatever weight specified and is manipulated by hand or used as a trailer. It consists of steel wheels, shaft 6 ft. by 2½ in. diameter adjustable tongue and reel guides.

Wire Gauges

Combined Table of Sizes in the Principal Wire Gauges

SOLID WIRE Diameters		Cross Section			GAUGE NUMBERS		SOLID WIRE		SOLID WIRE		STRANDED WIRE	
Mils	Millimeters	Square Mils	Circular Mils	Square Millimeters	American Wire Gauge (B. & S.)	Metric Wire Gauge	Diam. (Inches)	Cross Section (Square Inches)	Pounds per M Feet	Kilograms per Kilometer	Pounds per M Feet	Kilograms per Kilometer
1414.	35 93	1570800	2000000	1013 4	....	....	1 4142	1.5708	....	....	6175	9190
1323.	33 64	1374450	1750000	886 7	....	....	1 3229	1 3745	....	....	5403	8041
1225.	31 12	1178810	1500000	760 1	....	....	1 2247	1 1781	....	....	4631	6893
1118.	28 41	981750	1250000	633 4	....	....	1 1180	.9818	....	....	3859	5744
1000	25 40	785400	1000000	506 7	....	....	1 0000	7854	....	....	3087	4595
948.	24 09	706860	900000	456 0	....	....	.9487	.7069	....	....	2779	4136
894.	22.72	628320	800000	405 4	....	....	.8944	.6283	....	....	2470	3676
866	22 00	589050	750000	380 0	....	....	.8660	.5891	....	....	2316	3446
836 7	21 24	549780	700000	354 7	....	....	8367	.5498	....	....	2161	3217
774 6	19.67	471240	600000	304 0	....	....	.7746	.4712	....	....	1853	2757
707 1	17 96	392700	500000	253 4	....	....	.7071	3927	....	....	1544	2298
632 5	16.07	314160	400000	202 7	....	....	.6325	.3142	....	....	1235	1838
591 6	15 03	274890	350000	177 3	....	....	.5916	.2749	....	....	1081	1608
547.7	13 91	235620	300000	152 0	....	....	.5477	.2356	....	....	926	1379
500.	12 70	196300	250000	126.7	....	....	.500	.1963	757	1128	772	1151
490.	12 45	188600	240100	121 7	....	....	.490	.1886	727	1082	742	1104
464	11.79	169100	215300	109 1	....	....	.464	.1691	653	971	686	990
461 5	11 70	167300	213000	107 9	....	....	.4615	.1673	646	959	659	978
460.	11 68	166200	211600	107 2	4-0	....	.460	.1662	641	953	653	972
454.	11 53	161900	206100	104 4	....	....	.454	.1619	624	929	636	948
432.	10 97	146600	186600	94 56	....	....	.432	.1466	565	840	576	857
430.5	10 93	145600	185300	93 91	....	....	.4305	.1456	562	835	573	852
425	10 80	141900	180600	91 52	....	....	.425	.1419	547	813	558	829
409 6	10.40	131800	167800	85 03	3-0	....	.4096	.1318	508	756	518	771
400.	10 16	125700	160000	81 07	....	....	.400	.1257	484	720	494	734
393 8	10 00	121800	155100	78.58	....	....	.3938	.1218	469	698	478	712
393 7	10 00	121700	155000	78 54	....	100	.3937	.1217	468	697	477	711
380	9 652	113400	144400	73 17	....	....	.380	.1134	429	650	438	653
372.	9 449	108700	138400	70 12	....	....	.372	.1087	419	623	427	635
364.8	9 266	104500	133100	67 43	2-0	....	.3648	.1045	403	599	411	612
362 5	9 208	103200	131400	66 58	....	....	.3625	.1032	398	592	406	604
354 3	9 000	98610	125500	63 62	....	90	.3543	09861	380	566	388	577
348	8 839	95110	121100	61 36	....	....	.348	.09511	367	545	374	556
340.	8.636	90790	115600	58 58	....	....	.340	.09079	350	521	357	531
331.	8.407	86050	109600	55 52	....	....	.331	.08605	332	494	339	504
324.9	8 251	82890	105500	53 48	0	....	.3249	.08289	319	475	326	485
324	8 230	82450	105000	53 19	....	....	.324	.08245	318	472	324	481
315.	8 000	77910	99200	50 27	....	80	.315	.07791	305	447	311	462
306 5	7 785	73780	93940	47 60	....	....	.3065	.07378	284	423	290	431
300.	7 620	70690	90000	45 60	....	....	.300	.07069	273	406	278	413
289 3	7 348	65730	83690	42 41	1	....	.2893	.06573	253	377	258	385
284.	7 214	63350	80660	40 87	....	....	.284	.06335	244	363	249	370
283.	7.188	62900	80090	40 50	....	....	.283	.06290	242	361	247	368
276.	7 010	59830	76180	38 60	....	....	.276	.05983	231	343	236	350
275 6	7 000	59650	75950	38 48	....	70	.2756	.05965	230	342	235	349
262.5	6 668	54120	68910	34 92	....	....	.2625	.05412	209	310	213	316
259.	6.579	52690	67080	33 99	....	....	.259	.05269	203	302	207	308
257 6	6 544	52130	66370	33 63	2	....	.2576	.05213	201	299	205	305
252.	6 401	49880	63500	32 18	....	....	.252	.04988	193	286	197	292
243 7	6.190	46640	59390	30 09	....	....	.2437	.04664	180	267	184	272
238.	6.045	44490	56640	28 70	....	....	.238	.04449	173	255	176	260
236 2	6 000	43830	55800	28 27	....	60	.2362	.04383	169	251	172	256
232.	5.893	42270	53820	27 27	....	....	.232	.04227	163	242	166	247
229.4	5 827	41340	52630	26 67	3	....	.2294	.04134	159	237	162	242
225.3	5 723	39870	50760	25 72	....	....	.2253	.03987	154	228	157	233
220.	5.588	38010	48400	24 52	....	....	.220	.03801	147	217	150	221
212.	5.385	35700	44940	22 77	....	....	.212	.03530	136	202	139	206
207.	5.258	33650	42850	21 71	....	....	.207	.03365	130	193	133	197
204.3	5 189	32780	41740	21 15	4	....	.2043	.03278	126	188	129	192
203.	5.156	32370	41210	20 88	....	....	.203	.03237	125	186	128	190
196.8	5.000	30430	38750	19.63	....	50	.1968	.03043	117	174	119	177
192.	4.877	28950	36860	18.68	....	....	.1920	.02895	112	166	114	169

Wire Gauges (Continued)

Combined Table of Sizes in the Principal Wire Gauges

SOLID WIRE					GAUGE NUMBERS		SOLID WIRE		SOLID WIRE		STRANDED WIRE	
Diameters		Cross Section										
Mils	Milli-meters	Square Mils	Circular Mils	Square Milli-meters	American Wire Gauge (B. & S.)	Metric Wire Gauge	Diam. (Inches)	Cross Section (Square Inches)	Pounds per M Feet	Kilo-grams per Kilo-meter	Pounds per M Feet	Kilo-grams per Kilo-meter
181.9	4.621	26000	33100	16.77	5	....	.1819	.02600	100	148	102	152
180.	4.572	25450	32400	16.42	....	....	.180	.02545	98.0	146	100	149
177.2	4.500	24650	31390	15.90	....	45	.1772	.02466	94.9	141	96.8	144
177.	4.496	24610	31330	15.87	....	....	.177	.02461	94.8	141	96.7	144
176.	4.470	24330	30980	15.70	....	....	.176	.02433	93.6	139	95.5	142
165.	4.191	21380	27220	13.80	....	....	.165	.02138	82.3	123	90.0	134
162.	4.115	20620	26250	13.30	6	....	.162	.02062	79.5	118	81.1	120
160.	4.064	20110	25600	12.97	....	....	.160	.02011	77.5	115	79.1	117
157.5	4.000	19480	24810	12.57	....	40	.1575	.01948	75.1	112	76.6	114
148.3	3.767	17270	21990	11.14	....	....	.1483	.01727	66.5	99.0	67.8	101.0
148.	3.759	17200	21900	11.10	....	....	.148	.01720	66.3	98.6	67.6	100.6
144.3	3.665	16350	20820	10.55	7	....	.1443	.01635	63.0	93.7	64.3	95.6
144.	3.658	16290	20740	10.51	....	....	.144	.01629	62.8	93.4	64.1	95.3
137.8	3.500	14910	18990	9.621	....	35	.1378	.01491	57.5	85.5	58.7	87.2
135.	3.429	14310	18220	9.235	....	....	.135	.01431	55.2	82.0	56.3	83.6
134.	3.404	14100	17960	9.098	....	....	.134	.01410	54.3	80.8	55.4	82.4
128.5	3.264	12970	16510	8.366	8	....	.1285	.01297	50.0	74.4	51.0	75.9
128	3.251	12870	16380	8.302	....	....	.128	.01287	49.6	73.8	50.6	75.3
120.5	3.061	11400	14520	7.358	....	....	.1205	.01140	43.9	65.3	44.8	66.6
120.	3.048	11310	14400	7.297	....	....	.120	.01131	43.6	64.8	44.5	66.1
118.1	3.000	10960	13950	7.069	....	30	.1181	.01096	42.3	62.8	43.1	64.1
116.	2.946	10570	13460	6.818	9	....	.116	.01057	40.8	60.5	41.6	61.7
114.4	2.906	10280	13090	6.634	....	....	.1144	.01028	39.6	58.9	40.4	60.1
109.	2.769	9331	11880	6.020	....	....	.109	.009331	35.9	53.5	36.6	54.6
105.5	2.680	8742	11130	5.640	....	....	.1055	.008742	33.7	50.2	34.4	51.2
104.	2.642	8495	10820	5.481	....	....	.104	.008495	32.7	48.7	33.4	49.7
101.9	2.588	8155	10380	5.261	10	....	.1019	.008155	31.4	46.8	32.0	47.7
98.42	2.500	7609	9687	4.909	....	25	.09842	.007609	29.3	43.6	29.9	44.5
95.	2.413	7088	9025	4.573	....	....	.095	.007088	27.3	40.6	27.8	41.4
92.	2.337	6648	8464	4.289	....	....	.092	.006648	25.6	38.1	26.1	38.9
91.5	2.324	6576	8372	4.242	....	....	.0915	.006576	25.3	37.7	25.8	38.5
90.74	2.305	6467	8234	4.172	11	....	.09074	.006467	24.9	37.1	25.4	37.8
83.	2.108	5411	6889	3.491	....	....	.083	.005411	20.8	31.0	21.2	31.6
80.81	2.053	5129	6530	3.309	12	....	.08081	.005129	19.8	29.4	20.2	30.0
80.	2.032	5027	6400	3.243	....	....	.080	.005027	19.4	28.8	19.8	29.4
78.74	2.000	4869	6200	3.142	....	20	.07874	.004869	18.8	27.9	19.2	28.5
72.	1.829	4072	5184	2.627	....	....	.072	.004072	16.1	23.4	16.4	23.9
71.96	1.828	4067	5178	2.624	13	....	.07196	.004067	15.7	23.3	16.0	23.8
70.87	1.800	3944	5022	2.545	....	18	.07087	.003944	15.2	22.6	15.5	23.1
65.	1.651	3318	4225	2.141	....	....	.065	.003318	12.8	19.0	13.1	19.4
64.08	1.628	3225	4107	2.081	14	....	.06408	.003225	12.4	18.5	12.6	18.9
64	1.626	3217	4096	2.075	....	....	.064	.003217	12.3	18.4	12.5	18.8
62.99	1.600	3116	3968	2.011	....	16	.06299	.003116	12.0	17.8	12.2	18.2
62.5	1.588	3068	3906	1.979	....	....	.0625	.003068	11.8	17.6	12.0	18.0
58.	1.473	2642	3364	1.705	....	....	.058	.002642	10.2	15.1	10.4	15.4
57.07	1.450	2558	3257	1.650	15	....	.05707	.002558	9.86	14.7	10.1	15.0
56.	1.422	2463	3136	1.589	....	....	.056	.002463	9.52	14.1	9.71	14.4
55.12	1.400	2386	3038	1.539	....	14	.05512	.002386	9.21	13.7	9.39	14.0
54	1.372	2290	2916	1.478	....	....	.054	.002290	8.83	13.1	9.01	13.4
50.82	1.291	2028	2583	1.309	16	....	.05082	.002028	7.82	11.6	7.98	11.8
49	1.245	1886	2401	1.217	....	....	.049	.001886	7.27	10.8	7.42	11.0
48.	1.219	1810	2304	1.167	....	....	.048	.001810	6.98	10.4	7.02	10.6
47.5	1.207	1772	2256	1.143	....	....	.0475	.001772	6.84	10.2	6.98	10.4
47.24	1.200	1753	2232	1.131	....	12	.04724	.001753	6.76	10.0	6.90	10.3
45.26	1.150	1609	2048	1.038	17	....	.04526	.001609	6.20	9.23	6.32	9.41
42.	1.067	1385	1764	.8938	....	....	.042	.001385	5.34	7.94	5.45	8.10
41.	1.041	1320	1681	.8518	....	....	.041	.001320	5.09	7.57	5.19	7.72
40.3	1.024	1276	1624	.8231	18	....	.0403	.001276	4.92	7.32	5.02	7.47
40.	1.016	1257	1600	.8107	....	....	.040	.001257	4.84	7.21	4.94	7.35
39.37	1.000	1217	1550	.7854	....	10	.03937	.001217	4.70	6.98	4.79	7.12
36.	.9144	1018	1296	.6567	....	....	.036	.001018	3.93	5.84	4.01	5.96
35.89	.9116	1012	1288	.6527	19	....	.03589	.001012	3.90	5.80	3.98	5.92
35.43	.9000	986.1	1255	.6362	....	9	.03543	.0009861	3.82	5.77	3.90	5.81
35.	.8890	962.1	1225	.6207	....	....	.035	.0009621	3.71	5.52	3.78	5.62
34.8	.8839	951.1	1211	.6136	....	....	.0348	.0009511	3.67	5.46	3.74	5.57
32.	.8128	804.2	1024	.5189	....	....	.032	.0008042	3.11	4.62	3.17	4.71
31.96	.8118	802.3	1022	.5176	20	....	.03196	.0008023	3.09	4.60	3.15	4.69
31.7	.8052	789.2	1005	.5092	....	....	.0317	.0007892	3.04	4.53	3.10	4.62
31.5	.8000	779.1	992	.5027	....	8	.0315	.0007791	3.01	4.47	3.07	4.56

Wire Gauges (Continued)

(Solid)

Diameters		Cross Section			Gauge Numbers		Diam. (Inches)	Cross Section (Square Inches)	Weight	
Mils	Milli-meters	Square Mils	Circular Mils	Square Milli-meters	American Wire Gauge (B. & S.)	Metric Wire Gauge			Pounds per M Feet	Kilo-grams per Kilo-meter
28.6	.7264	642.4	818.0	.4145	....	....	.0286	.0006424	2.47	3.68
28.46	.7229	636.3	810.1	.4105	21	....	.02846	.0006363	2.45	3.65
28	.7112	615.8	784.0	.3973	....	....	.028	.0006158	2.37	3.53
27.56	.7000	596.5	759.5	.3848	....	7	.02756	.0005965	2.29	3.42
25.8	.6553	522.8	665.6	.3373	....	....	.0258	.0005228	2.13	3.00
25.35	.6438	504.6	642.4	.3255	22	....	.02535	.0005046	1.94	2.89
25.	.6350	490.9	625.0	.3167	....	....	.025	.0004909	1.89	2.82
24.	.6096	452.4	576.0	.2919	....	....	.024	.0004524	1.74	2.59
23.62	.6000	438.3	558.0	.2828	....	6	.02362	.0004383	1.69	2.52
23.	.5842	415.5	529.0	.2675	....	....	.023	.0004155	1.60	2.38
22.57	.5733	400.1	509.5	.2582	23	....	.02257	.0004001	1.54	2.30
22.	.5588	380.1	484.0	.2452	....	....	.022	.0003801	1.46	2.18
20.4	.5182	326.9	416.2	.2109	....	....	.0204	.0003269	1.26	1.88
20.1	.5106	317.3	404.0	.2047	24	....	.0201	.0003173	1.22	1.82
20.	.5080	314.2	400.0	.2027	....	....	.020	.0003142	1.21	1.80
19.68	.5000	304.3	387.5	.1963	....	5	.01968	.0003043	1.17	1.75
18.1	.4597	257.3	327.6	.1660	....	....	.0181	.0002573	.992	1.48
18.	.4572	254.5	324.0	.1642	....	....	.018	.0002545	.982	1.46
17.9	.4547	251.7	320.4	.1624	25	....	.0179	.0002517	.970	1.44
17.72	.4500	246.5	313.9	.1590	....	4.5	.01772	.0002465	.951	1.42
17.3	.4394	235.1	299.3	.1517	....	....	.0173	.0002351	.906	1.35
16.4	.4166	211.2	269.0	.1363	....	....	.0164	.0002112	[illegible]	1.21
16.2	.4115	206.1	262.4	.1330	....	....	.0162	.0002061	[illegible]	1.18
16.	.4064	201.1	256.0	.1297	....	....	.016	.0002011	[illegible]	1.15
15.94	.4049	199.6	254.1	.1288	26	....	.01594	.0001996	[illegible]	1.16
15.75	.4000	194.8	248.0	.1257	....	4	.01575	.0001948	.751	1.12
15.	.3810	176.7	225.0	.1140	....	....	.015	.0001767	.682	1.01
14.8	.3759	172.0	219.0	.1110	....	....	.0148	.0001720	.663	.987
14.2	.3606	158.3	201.5	.1021	27	....	.0142	.0001583	.610	.908
14.	.3556	153.9	196.0	.09932	....	....	.014	.0001539	.593	.883
13.78	.3500	149.1	189.9	.09621	....	3.5	.01378	.0001491	.575	.855
13.6	.3454	145.3	185.0	.09372	....	....	.0136	.0001453	.560	.834
13.2	.3353	136.8	174.2	.08829	....	....	.0132	.0001368	.527	.785
13.	.3302	132.7	169.0	.08563	....	....	.013	.0001327	.511	.762
12.8	.3251	128.7	163.8	.08302	....	....	.0128	.0001287	.496	.738
12.64	.3211	125.5	159.8	.08098	28	....	.01264	.0001255	.484	.720
12.4	.3150	120.8	153.8	.07791	....	....	.0124	.0001208	.465	.693
12.	.3048	113.1	144.0	.07297	....	....	.012	.0001131	.437	.649
11.81	.3000	109.6	139.5	.07069	....	3	.01181	.0001096	.423	.628
11.8	.2997	109.4	139.2	.07055	....	....	.0118	.0001094	.422	.627
11.6	.2946	105.7	134.6	.06818	....	....	.0116	.0001057	.406	.606
11.26	.2859	99.54	126.7	.06422	29	....	.01126	.00009954	.384	.571
10.8	.2743	91.61	116.6	.05910	....	....	.0108	.00009161	.353	.525
10.4	.2642	84.95	108.2	.05481	....	....	.0104	.00008495	.327	.486
10.03	.2546	78.94	100.5	.05093	30	....	.01003	.00007894	.304	.453
10.	.2540	78.54	100.0	.05067	....	....	.010	.00007854	.302	.451
9.842	.2500	76.08	96.87	.04909	....	2.5	.009842	.00007609	.293	.436
9.5	.2413	70.88	90.25	.04573	....	....	.0095	.00007088	.273	.407
9.2	.2337	66.48	84.64	.04289	....	....	.0092	.00006648	.256	.382
9.	.2286	63.62	81.00	.04104	....	....	.009	.00006362	.245	.365
8.928	.2268	62.60	79.70	.04039	31	....	.008928	.00006260	.241	.359

Wire Gauges (Concluded)

(Solid)

Diameter		Cross Section			Gauge Numbers				Weight	
Mils	Millimeters	Square Mils	Circular Mils	Square Millimeters	American Wire Gauge (B & S)	Metric Wire Gauge	Diam. (Inches)	Cross Section (Square Inches)	Pounds per M Feet	Kilograms per Kilometer
8.5	.2159	56.75	72.25	.03661	....	....	.0085	.00005675	.219	.326
8.4	.2134	55.42	70.56	.03575	....	....	.0084	.00005542	.213	.318
8	.2032	50.27	64.00	.03243	..	....	.008	.00005027	.194	.290
7.95	.2019	49.64	63.21	.03203	32	....	.00795	.00004964	.191	.285
7.874	.2000	48.69	62.00	.03142	....	2	.007874	.00004869	.188	.280
7.6	.1930	45.36	57.76	.02927	..	.	.0076	.00004536	.175	.260
7.5	.1905	44.18	56.25	.02850	....	....	.0075	.00004418	.170	.253
7.087	.1800	39.44	50.22	.02545	....	1.8	.007087	.00003944	.153	.227
7.08	.1798	39.37	50.13	.02540	33	...	.00708	.00003937	.152	.226
7	.1778	38.48	49.00	.02483	....	....	.007	.00003848	.148	.221
6.8	.1727	36.32	46.24	.02343	....	....	.0068	.00003632	.139	.208
6.6	.1676	34.21	43.56	.02207	..	...	.0066	.00003421	.131	.196
6.305	.1601	31.22	39.75	.02014	34	....	.006305	.00003122	.120	.179
6.299	.1600	31.16	39.68	.02011	....	1.6	.006299	.00003116	.119	.178
6.2	.1575	30.19	38.44	.01948	....	....	.0062	.00003019	.116	.173
6	.1524	28.27	36.00	.01824	....	....	.006	.00002827	.108	.162
5.906	.1500	27.39	34.87	.01767	....	1.5	.005906	.00002739	.105	.157
5.8	.1473	26.42	33.64	.01705	...	....	.0058	.00002642	.102	.151
5.615	.1426	24.76	31.52	.01597	35	....	.005615	.00002476	.0954	.142
5.512	.1400	23.86	30.38	.01539	....	1.4	.005512	.00002386	.0920	.136
5.5	.1397	23.76	30.25	.01533	....	....	.0055	.00002376	.0916	.136
5.2	.1321	21.24	27.04	.01370	....	....	.0052	.00002124	.0818	.121
5.	.1270	19.63	25.00	.01267	36	....	.005	.00001963	.0757	.113
4.8	.1219	18.10	23.04	.01167	...	....	.0048	.00001810	.0698	.104
4.724	.1200	17.53	22.32	.01131	....	1.2	.004724	.00001753	.0676	.101
4.6	.1168	16.62	21.16	.01072	....	....	.0046	.00001662	.0641	.0954
4.453	.1131	15.57	19.83	.01005	37	....	.004453	.00001557	.0600	.0893
4.4	.1118	15.21	19.36	.009810	....	....	.0044	.00001521	.0587	.0873
4.	.1016	12.57	16.00	.008107	....	....	.004	.00001257	.0484	.0721
3.965	.1007	12.35	15.72	.007967	38	....	.003965	.00001235	.0476	.0708
3.937	.1000	12.17	15.50	.007854	....	1	.003937	.00001217	.0468	.0698
3.6	.09144	10.18	12.96	.006567	....	....	.0036	.00001018	.0392	.0584
3.531	.08969	9.793	12.47	.006318	39	....	.003531	.000009793	.0377	.0562
3.2	.08128	8.042	10.24	.005189	....	....	.0032	.000008042	.0310	.0462
3.145	.07987	7.766	9.888	.005010	40	....	.003145	.000007766	.0299	.0445
2.8	.07113	6.159	7.842	.003973	41	....	.0028	.000006159	.0237	.0354
2.8	.07112	6.158	7.840	.003973	....	....	.0028	.000006158	.0237	.0354
2.494	.06334	4.884	6.219	.003151	42	....	.002494	.000004884	.0188	.0280
2.4	.06096	4.524	5.760	.002919	..	....	.0024	.000004524	.0174	.0260
2.221	.05641	3.873	4.932	.002499	43	....	.002221	.000003873	.0149	.0222
2.	.05080	3.142	4.000	.002027	....	....	.002	.000003142	.0121	.0180
1.978	.05023	3.072	3.911	.001982	44	....	.001978	.000003072	.0118	.0176
1.969	.05000	3.044	3.875	.001963	....	0.5	.001969	.000003044	.0117	.0175
1.761	.04473	2.436	3.102	.001572	45	....	.001761	.000002436	.0094	.0140
1.6	.04064	2.011	2.560	.001297	....	....	.0016	.000002011	.0077	.0115
1.568	.03984	1.932	2.460	.001246	46	....	.001568	.000001932	.0074	.0111
1.397	.03547	1.532	1.951	.0009884	47	....	.001397	.000001532	.0059	.0088
1.243	.03158	1.215	1.547	.0007836	48	....	.001243	.000001215	.0047	.0070
1.2	.03048	1.131	1.440	.0007297	....	....	.0012	.000001131	.0044	.0065
1.107	.02812	.9635	1.227	.0006216	49	....	.001107	.0000009635	.0037	.0055
1.	.02540	.7854	1.000	.0005067	....	....	.001	.0000007854	.0030	.0045
.9843	.02500	.7641	.9720	.0004929	50	....	.0009843	.0000007641	.0029	.0044

TEST QUESTIONS

1. *What are the three essential elements of an underground system?*
2. *Give three general classes of underground systems.*
3. *When cables are laid directly in the ground, what is depended upon for mechanical protection?*
4. *Name two general classes of clay conduit.*
5. *Describe a conduit transposition unit.*
6. *What kind of conduit unit is used on curves?*
7. *Describe the method of laying single duct vitrified clay conduit, also for laying multi-duct conduit.*
8. *What is trough conduit and how is it laid?*
9. *How are concrete conduits usually constructed?*
10. *How are the ducts formed in wooden conduits?*
11. *Name two types of wooden conduit, and describe them.*
12. *In what lengths can the trough type of wooden conduit be laid.*
13. *How are wrought iron or steel conduits made?*
14. *Describe two methods of laying steel conduits.*
15. *Is steel or wrought iron preferable?*
16. *What may be said with respect to cast iron conduit?*
17. *Of what does a fibre conduit consist?*
18. *Name three types of joint available for connecting the lengths of fibre conduit.*
19. *Describe the tier by tier method of laying fibre conduit.*

20. *How is conduit laid by the built-up method?*
21. *Describe the construction of manholes.*
22. *Give methods of draining underground conduit.*
23. *Describe in detail the pulling in of the cables.*

CHAPTER 123

Cable Jointing

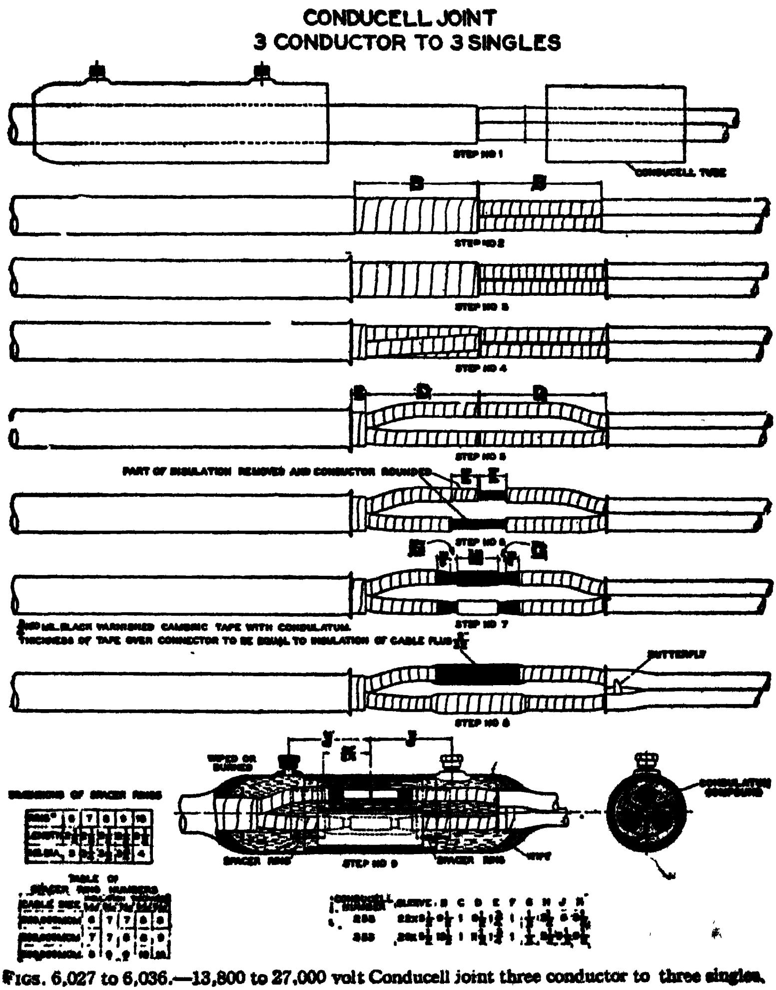
As explained in Chapter 100, the author objects to the generally accepted use of the terms *joints* and *splices*, and accordingly, this Chapter is called Cable Jointing and not Cable Splicing. The student of cable jointing will find that there are numerous types of joint met with in practice. These various joints may be classified

1. With respect to voltage

   a. 100 to 240
   b. 2,300 to 3,000
   c. 7,800 to 13,800
   d. 27,000
   e. 45,000
   f. 132,000

2. With respect to insulation

   a. Cotton tape
   b. Rubber
   c. Cambric
   d. Paper



FIGS. 6,027 to 6,036.—13,800 to 27,000 volt Conducell joint three conductor to three singles.

3. With respect to conductors
   a. Single
   b. Duplex
   c. Three conductor
   d. Four conductor
   etc.

Lead work forms an important part of the operations of cable jointing and as a preliminary the student should study soldering in its various branches and joint wiping.

Before attempting to wipe a sleeve joint on a cable, the student should practice wiping a joint on an ordinary lead pipe. In addition to the

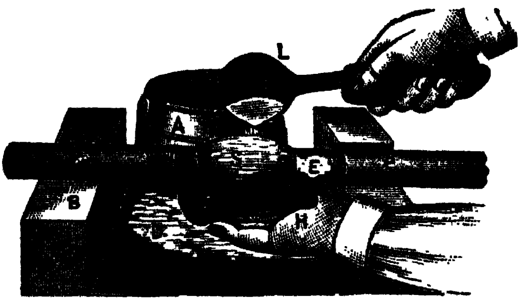


FIG. 6,037.—Method of wiping a horizontal joint. The *cloth* used for wiping is a pad of moleskin or fustian about four inches square made from a piece twelve inches by nine, folded six times, and sewed to keep it from opening; the side next the pipe is saturated with hot tallow when used. If the lead has been brought to the heat of the solder, and the latter properly manipulated and shaped while in a semi-fluid or plastic condition, the joint gradually assumes the finished egg shaped appearance. In making the joint a quantity of solder is taken from the pot by means of the ladle, the solder being previously heated so hot that the hand can be kept within two inches of its surface. The solder is poured lightly on the joint, the ladle being moved backwards and forwards, so that too much solder is not put in one place. The solder is also poured an inch or two on the soiling, to make the pipe of proper temperature. Naturally the further the heat is run or taken along the pipe, the better the chance of making the joint. The operator keeps pouring and with the left hand holds the cloth to catch the solder, and also to cause the same to tin the lower side of the pipe, and to keep the solder fron dropping down. By the process of steady pouring the solder now becomes nice and soft and begins to feel shaped, firm and bulky. When in this shape and in a semi-fluid condition the ladle is put down, and, with the left hand, the operation of wiping, as illustrated, is begun working from the soiling toward the top of the bulb. If the lead cool rapidly, it is reheated to a plastic condition by a torch, or a heated iron. When the joint is completed, it is cooled with a water spray, so that the lead shall not have time to alter its shape.

instructions given in this chapter on lead work, a study of this subject as given in volume No. 1 of the author's Plumbers and Steam Fitters Guides is recommended.

The operations to be performed in wiping the various types of joint are in general very much the same, differing chiefly in the proportions of the joint, kind and quantity of material to be used, etc.

Detailed instructions will now be given for wiping joints on type cables largely used.

Jointing 13,800 Volt, 3 Conductor Cable.—This cable takes a 5½×22 lead sleeve and 350,000 *cm.* connector. The cable is paper insulated; conductors 7×7⁄32 insulation. Straight joint. The following materials are used:

1	lead sleeve 5½" *i.d.* ⅛" wall 22" long.
1	Conducell No. 253.
3	350,000 *cm.* copper sleeve connectors.
108	yards ¾×10 mils black varnished cambric tape.
6	lbs. wiping solder (40 tin 60 lead).
12½	lbs. Condulatum.
2	oz. waste ends.
1	oz. Stearine flux.
15	ins. Melrose cord.
1	yard ½" white tape.
1	sheet 00 emery cloth.
7	paper pasters.

Instructions will now be given for performing the various operations in jointing.

Training.—The term "training" indicates the shaping of the two cables where they project into the manhole so that they will follow the contour of the walls and come together at the point where they are to be joined, with their ends overlapping.

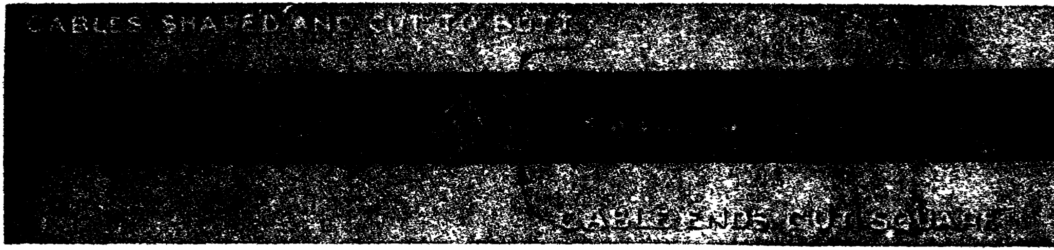


Fig. 6,038.—Appearance of cables after being cut "square" to exact length to butt.

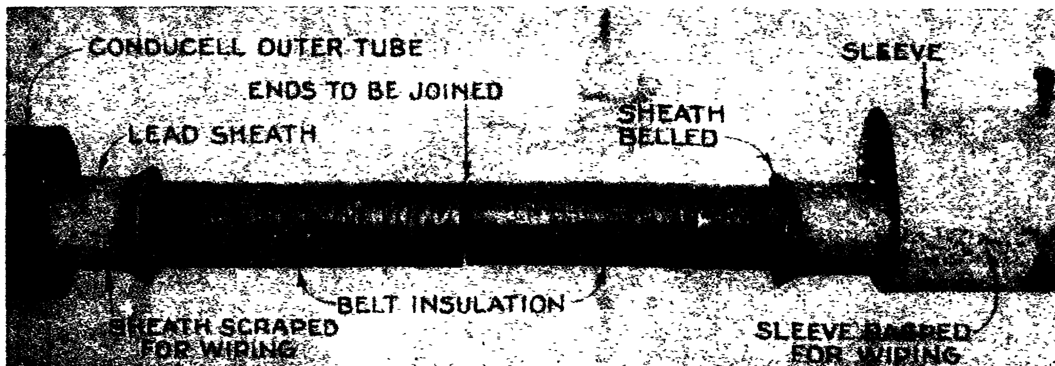


Fig. 6,039.—Appearance of cables in position with lead sheath removed and sheath ends belled. Note sleeve and Conducell outer tube threaded on cables. The sleeve should be scraped back from each end a distance of about 3 ins. as these portions of the sleeve will later be covered with solder in the wiping operation.

In training, care should be taken to handle the cables so as not to give them any sharp bend. The cable should be supported by brackets or hangers.

Cutting Cable Ends.—Mark the two overlapping cables at the point where they are to be joined, and take the precaution to cut

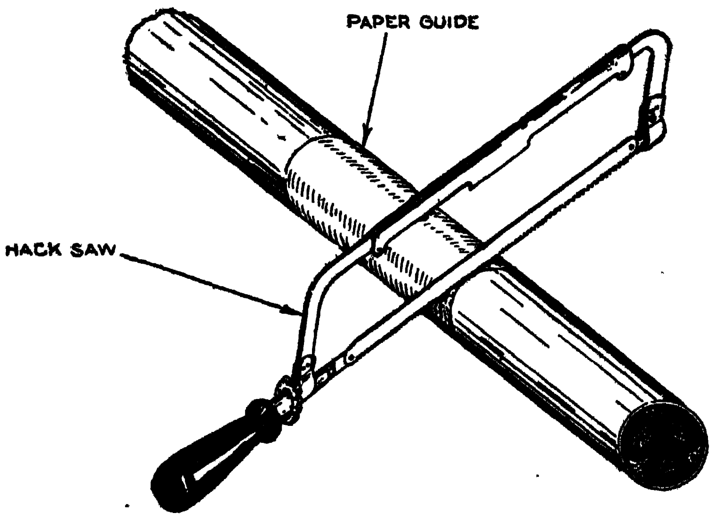


FIG. 6,040.—Paper guide for cutting off cable "square." The beginner should wrap a paper guide around the cable at the point where it is to be cut, as shown, which will serve as a guide for the hack saw

them square with a hack saw. They should be so cut that the ends which are to be joined butt up against each other, that is, no space between as in fig. 6,038.

To facilitate cutting off cable square, wrap paper guide around the cable as in fig. 6,040.

Ringing.—Mark with a knife the point where the lead sheath is to be removed on each cable, this will be 9½ ins. from the

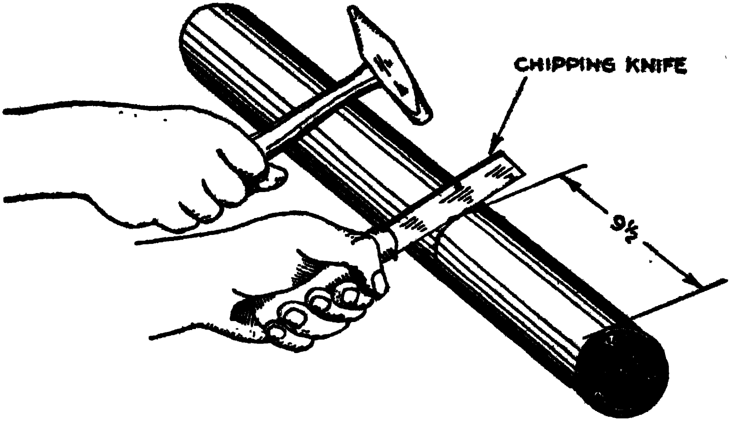


FIG. 6,041.—Ringing operation. After cable has been trained on racks measure back 9½ ins. from cut and ring lead sheath with a chipping knife and hammer as shown.

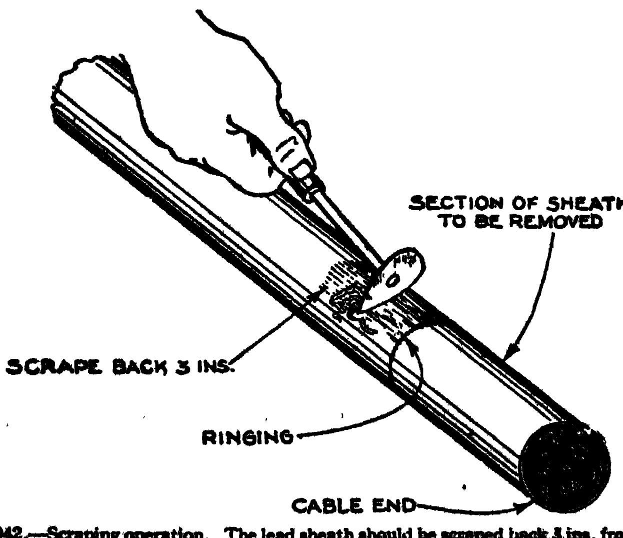


FIG. 6,042.—Scraping operation. The lead sheath should be scraped back 3 ins. from the point of ringing, as shown. After scraping rub the scraped part with Stearine flux.

point where the cable was cut. This 9½ ins. is the length of lead sheath to be removed. Ring each cable sheath along the circumferential marks with a chipping knife, as shown in fig. 6,041. Scrape the lead sheath of each cable three inches back

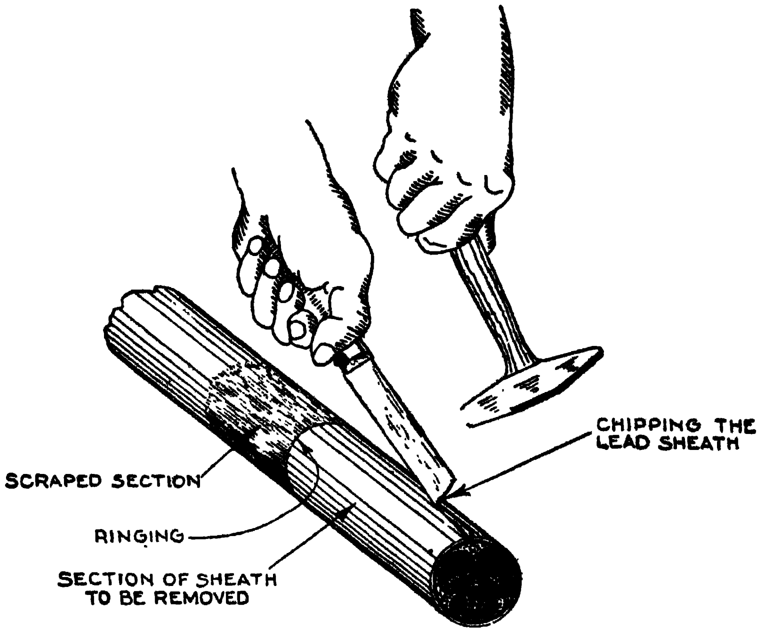


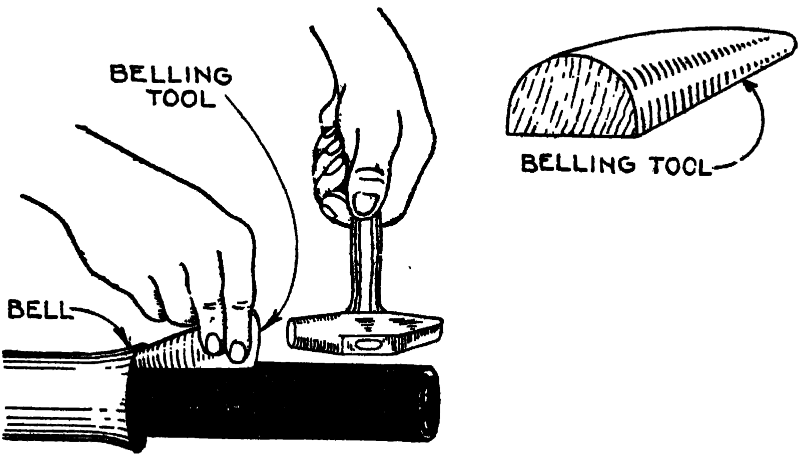
FIG. 6,043.—Splitting operation. The lead sheath must be removed from the end of the cable to the point of ringing. It is first split by chipping with a chipping knife as shown. After the sheath has been split it is easily twisted off with the aid of a pair of pliers.

from the point of ringing, as in fig. 6,042. After scraping, rub the scraped part with flux (Stearine).

Removing the Sheath.—From the end of the cable to the point of ringing, the lead sheath should be split with a chipping

knife as shown in fig. 6,043, after which it can be easily removed. Note the angle at which the chipping knife is held in splitting. Be careful not to damage the insulation in clipping.

Belling.—The term "bell" means to flare out. The end of the lead sheath is now belled, as shown in fig. 6,044, using a blunt



FIGS. 6,044 and 6,045.—Belling operation and belling tool. The end of the lead sheath is flared out by using the belling tool, fig. 6,045 as shown in fig. 6,044. Flare out the sheath about ½ in.

nosed tool of hard wood or fibre, such as shown in fig. 6,045. In performing this operation, care should be taken not to cut the insulation.

Removing Insulation and Shaping.—Remove the overall or belt insulation to a point 1 in. from bell, that is, the edge of the lead sheath, as shown in fig. 6,047.

Next, cut the jute fillers at a point close to the end of the belt insulation, as shown in fig. 6,048.

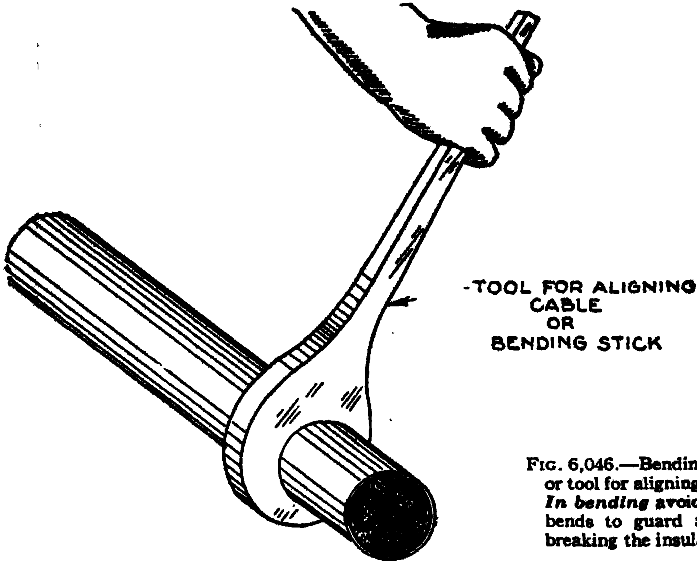


FIG. 6,046.—Bending stick or tool for aligning cable. ***In bending*** avoid sharp bends to guard against breaking the insulation.

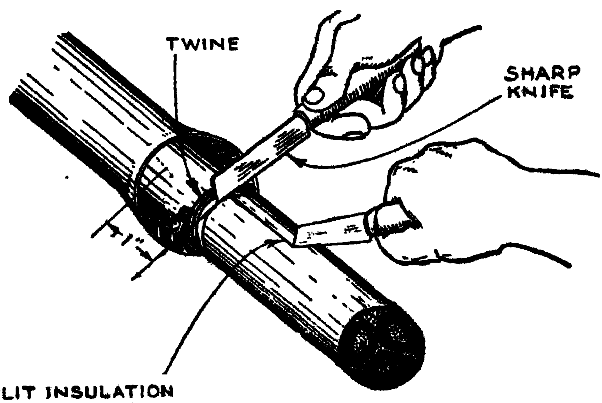


FIG. 6,047.—Removing belt insulation. The belt insulation must be removed from the end of the cable to within a distance of 1 in. from the bell. ***In doing this*** be careful not to injure the insulation over each conductor. In removing the belt insulation first wrap twine around the insulation extending 1 in. from sheath; this is to prevent the insulation unraveling. The illustration shows the various operations.

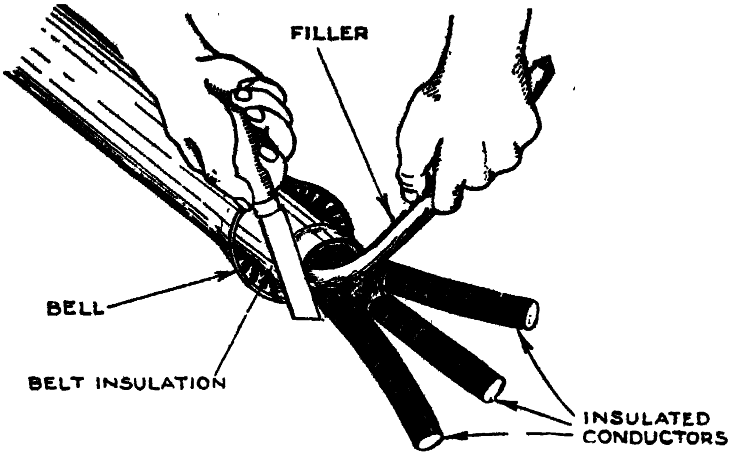


FIG. 6,048.—Cutting the fillers. This cable has four fillers and all of them should be cut close to the end of the inch margin of belt insulation left around the insulated conductors.

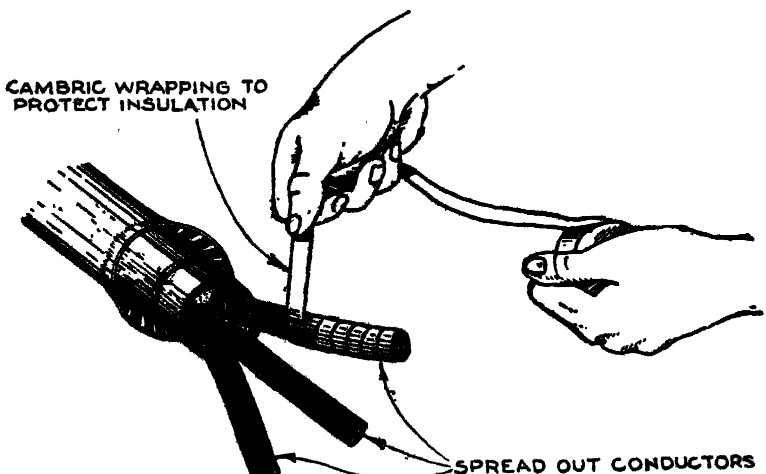
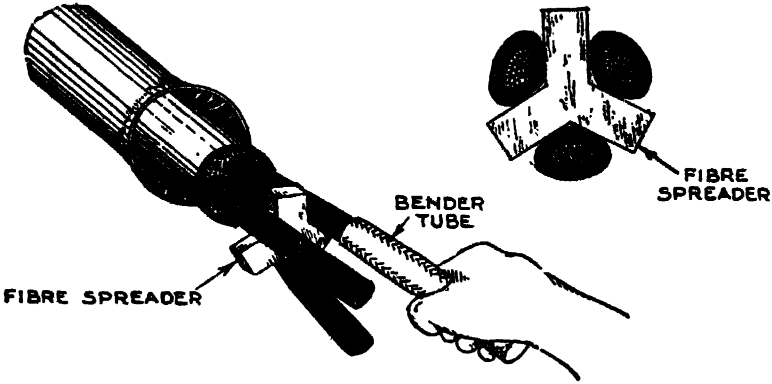


FIG. 6,049.—Spreading operation. Before spreading out the three conductors, wrap each with cambric tape as shown to prevent injuring the insulation. Do not spread out conductors more than necessary, and thus avoid chance of breaking the mill insulation at crutch.

At this stage, the lead sleeve and mica tube of the Conducell should be slipped on the cable so that when the conductors have been joined and insulated, it may be slid into place over the joint preparatory to wiping.



FIGS. 6,050 and 6,051.—Insertion of spreader and shaping. *After* the conductors have been spread out to the desired extent, they are held apart by means of a spreader or fibre block, as shown in detail in fig. 6,051. After inserting the spreader, the conductors are shaped or slightly bent inward by means of the bender tube, as shown.

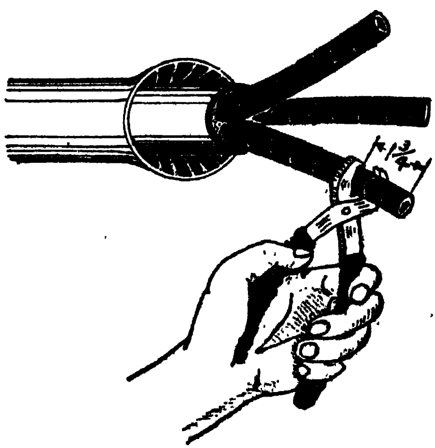


FIG. 6,052.—Removing half of insulation from conductors with insulation cutter. Measure back 1¾ ins. from end of conductor and cut off half of the insulation. The reason for removing only half of the insulation is explained in fig. 6,053.

Before slipping on the lead sleeve, rasp both ends to give a clean bright surface and candle. The conductors should now be shaped and retained so by the use of a spreader or separator as shown in figs. 6,050, 6,051 and 6,054, the insulation being protected by wrapping each conductor as in fig. 6,049.

Since the conductors with insulation are pretty stiff, they are conveniently bent in the desired position by the use of a fibre tube, shown in fig. 6,050, previously inserting spaces and wrapping conductors with protective tape.

Some of the accompanying illustrations show only one conductor; this is to bring out more clearly some of the operations preparatory to sweating.

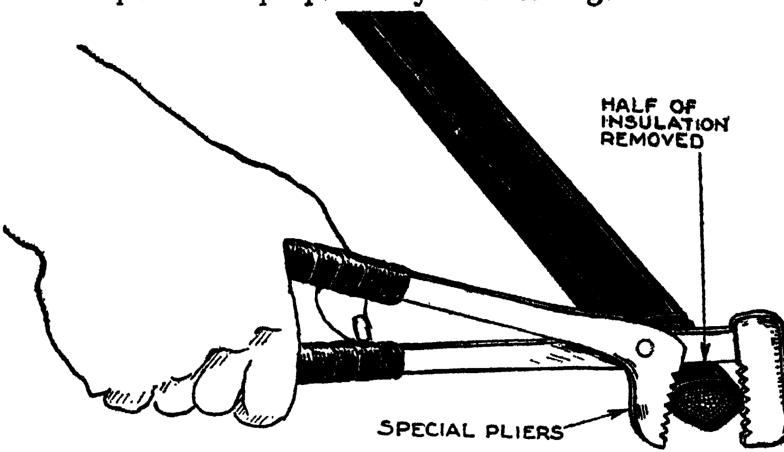


FIG. 6,053.—Rounding or shaping conductor strands. It will be noticed that the conductor stranding is of sector form, and this must be brought to circular form so that the connector can later be properly put on. The operation is easily done by means of the special claw plier tool here shown, although ordinary gas pliers are generally used. The belt of insulation left over the conductor protects the strands from the teeth of the pliers. After shaping, this insulation is removed exposing the conductor.

Rounding.—Measure off 1¾ ins. from end of conductors and cut off half of the insulation with an insulation cutter, as shown in fig. 6,052. The conductor strands should be shaped to the form of a circle, that is *rounded*, by the use of gas pliers, or the special wrench shown in fig. 6,053.

FIG. 6,054 —Appearance of cables in position with lead sheath removed and sheath ends belled. Note treatment of conductors to be joined.

The remaining half of the insulation which was left at the end of the conductor was for the purpose of preventing injury to the strands during the rounding operation just described. This half of the insulation is now removed; that is, the remaining half of the insulation is removed back $1\frac{3}{4}$ ins.

Placing Connectors and Sweating.—Put the conductors in alignment and place over each butting pair a split connector. Squeeze up connector with gas pliers, using paper or other protecting layer between pliers and connector, as shown in fig. 6,055 (for one conductor).

During this operation one or more of the strands may be squeezed out of the connector; if so, they are easily bedded by the use of the special pliers shown in fig. 6,056.

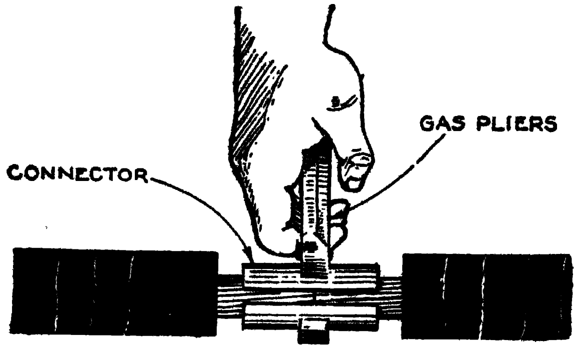


FIG. 6,055.—Placing connector over conductors. Put each pair of butting conductors in line. Open up the connector so it can be placed around the conductors and then squeeze up with pliers so that it tightly grips the conductors. It should be so placed that the conductors come together at the middle point of the connector. In using the pliers on the connector, wrap some cloth around the connector to protect it from the teeth of the pliers.

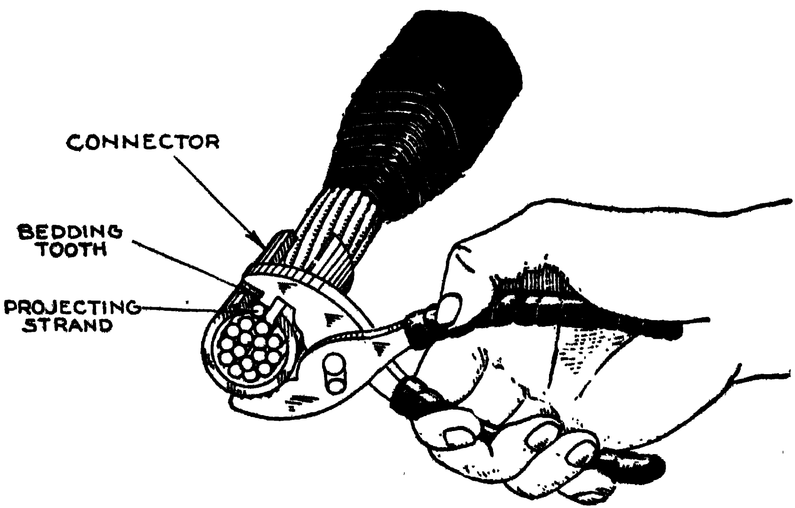


FIG. 6,056.—Special "bedding" pliers. This convenient tool is easily made from ordinary pliers by filing the jaw to the shape shown. *In attaching* the connector, sometimes one or more strands may be pushed up so that the connector cannot be squeezed together. Any strand is easily embedded by means of the pliers, as shown.

The edge of the insulation on conductors should be wrapped tightly with cotton tape as shown in fig. 6,057 and tied in place to protect the insulation from charring during the sweating operation, and to prevent the solder running under the insulation. Remove tape after sweating.

Flux the joints to be sweated with Stearine or a solution of rosin and alcohol.

In sweating the joint, thoroughly saturate by repeated pourings of the hot solder as in fig. 6,058, using fresh solder from the

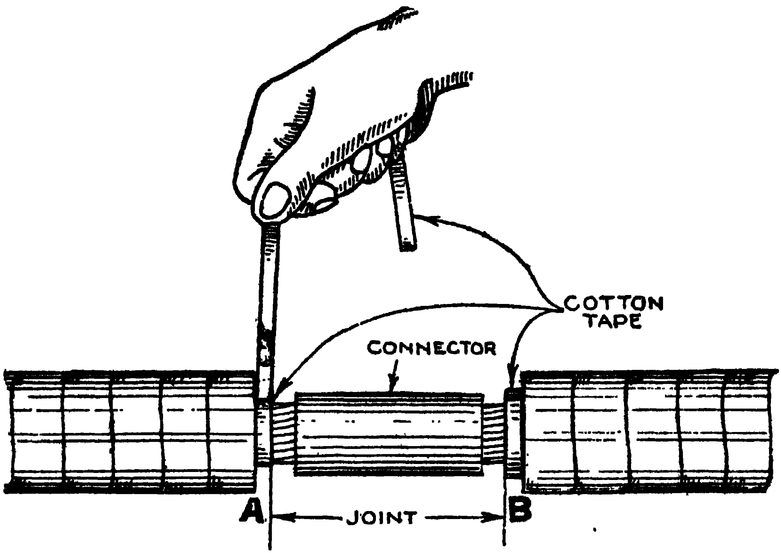


FIG. 6,057.—Preparing a joint for sweating. Wrap cotton tape around conductors at A and B, to prevent solder running beyond these points during the sweating operation. This tape thus defines the limit of the joint proper, that is to say, the soldered portion. *It should be noticed that in this and several other illustrations only one conductor is shown, in order to show the parts larger and more plainly.*

pot for each pouring. To "build up" pour the same solder, from ladle to ladle, two or three times until the temperature is sufficiently lowered for the solder to become plastic. After the joint has been properly built up, smooth the surface by wiping

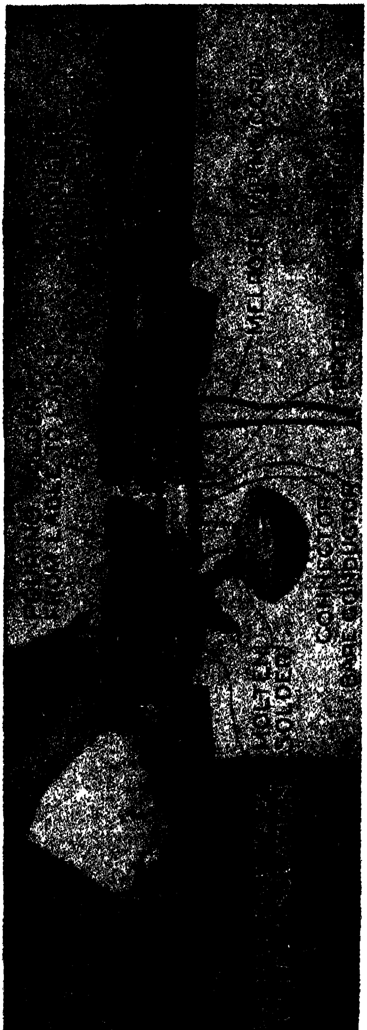


FIG. 6,058.—Method of sweating the connectors by pouring the hot solder from ladle to ladle. Note Melrose cord reading for wiping.

FIG. 6,059.—Appearance of Joints after they have been sweated and wiped with a piece of Melrose cord, and the insulation pencilled. Note separators, and spacing rings of the Conducell.

with a piece of melrose cord, as in fig. 6,060. The appearance of these joints at this stage is shown in fig. 6,059.

After wiping with Melrose cord, make a final finish with emery cloth, and thoroughly clean the parts of emery dust. The other two joints should be sweated in a similar manner.

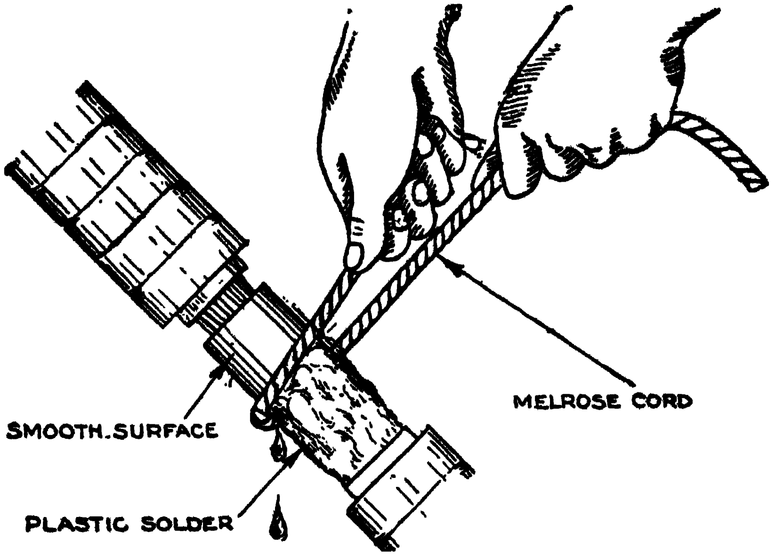


FIG. 6,060.—Use of Melrose cord in cleaning off sweat. Owing to the proximity of the other conductors, a joint cannot be sweated with the ordinary cloth, and accordingly a piece of Melrose cord is used instead, as shown. Fig. 6,058 clearly shows the difficulty in using a cloth in sweating on account of the nearness of the other conductors.

After the three joints have been sweated and cleaned as just described, remove the cotton tape which was placed over the edge of the insulation and also the protective tape wrapping shown in fig. 6,059.

Penciling.—The insulation around each conductor should be "penciled" back 1 in. This is done much in the same way as sharpening a lead pencil. *It is important that the penciling be smooth and even.*

Use a very sharp knife or special tool in penciling the insulation, and be careful not to nick the conductors. The operation of penciling is shown in fig. 6,061 and the appearance of the penciled joints in fig. 6,059.

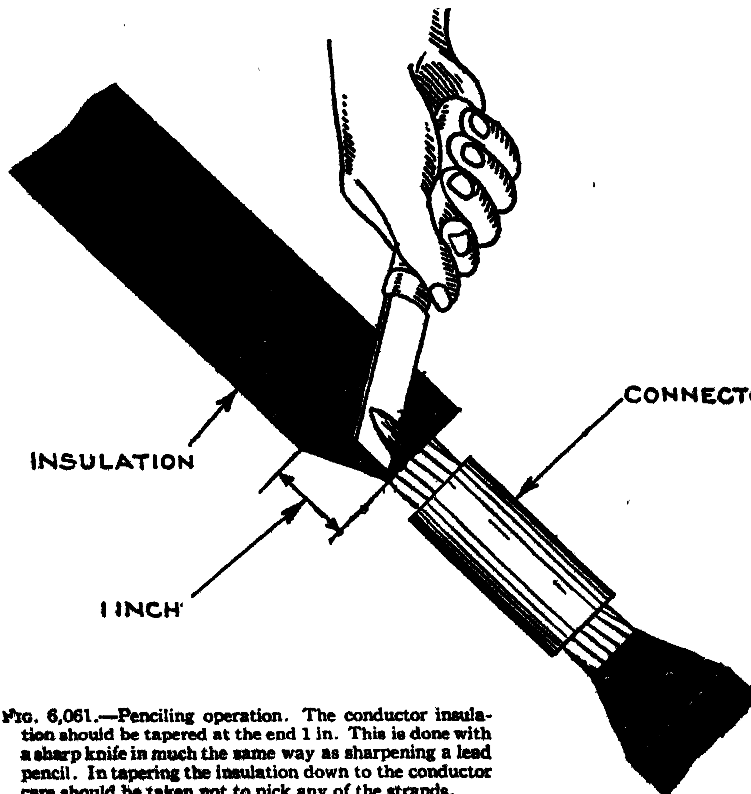


FIG. 6,061.—Penciling operation. The conductor insulation should be tapered at the end 1 in. This is done with a sharp knife in much the same way as sharpening a lead pencil. In tapering the insulation down to the conductor care should be taken not to nick any of the strands.

Boiling Out.—The joints should now be boiled out with hot condulatum 240° Fahr. using a dipper. *Condulatum is a by-product of petroleum.* After boiling out, paint *with hot condulatum.*

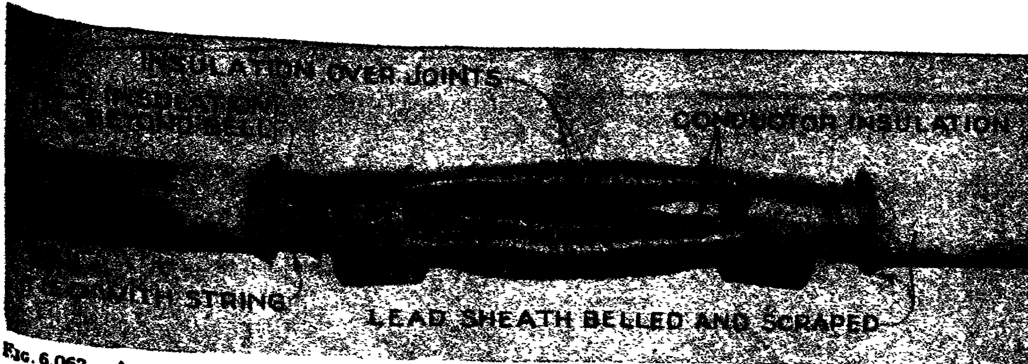


FIG. 6,062.—Appearance of joints after they have been insulated. Note lead sheath ends belled and scraped, also belt insulation projecting 1 in. and secured by a string so that it will not unravel. At this stage the separators are removed.

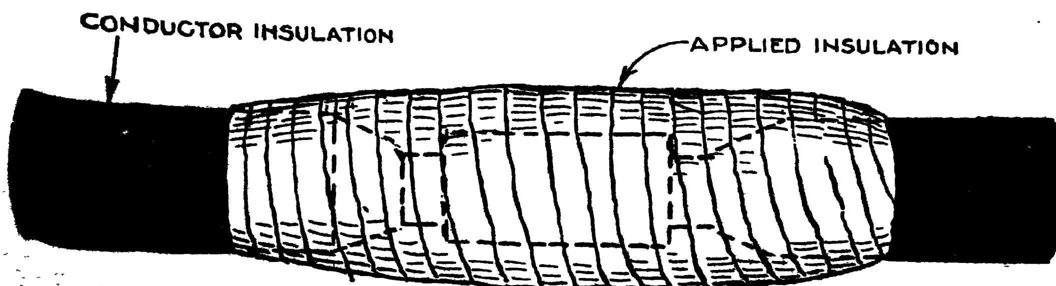
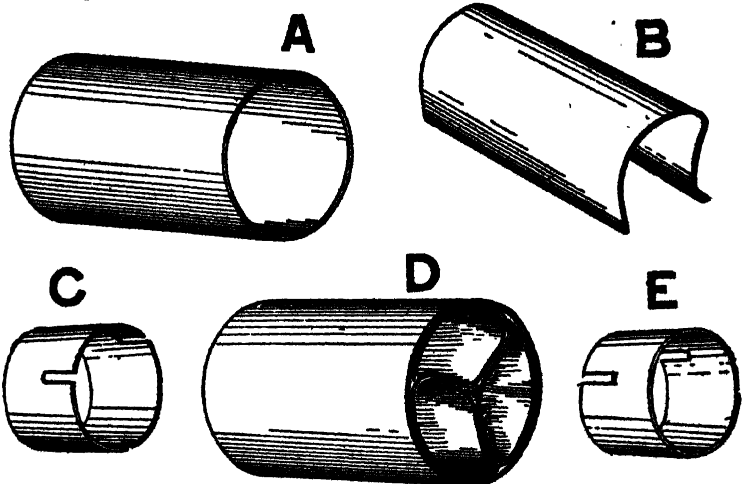


FIG. 6,063.—Insulating conductors. Each conductor should be wrapped with ¾ in. cambric tape. Build up the taping 1¼ in. over the connector. The taping should extend 1 in. back of the penciling. In wrapping the tape let it overlap 50%; this is called half lap. Paint each layer with hot condulatum.

Insulating.—The joints should now be insulated by wrapping them with cambric tape and painting each layer with hot condulatum as shown in figs. 6,062 and 6,063. Build up the taping 13/32 over the connector and extending 1 in. back of the penciling.



FIGS. 6,064 to 6,068.—Conducell insulating and spacing unit showing parts and assembly. The unit consists of three inner separating pieces, fig. B, held in position by two spacing rings figs. C and E, and a sleeve, fig. A. The assembly is shown in fig. D.

Assembling the Conducell.—The Conducell for a three conductor cable consists of an outer seamless tube, as shown in fig. 6,064, three similarly formed curved inner separating pieces, shown in fig. 6,065, and two end spacing rings, shown in figs. 6,066 and 6,068, the assembly being shown in fig. 6,067. This assembly forms three separate cells for the conductors, the parts being interlocked among themselves. The operations of assembling the Conducell over the conductors are shown in figs. 6,069 to 6,071.

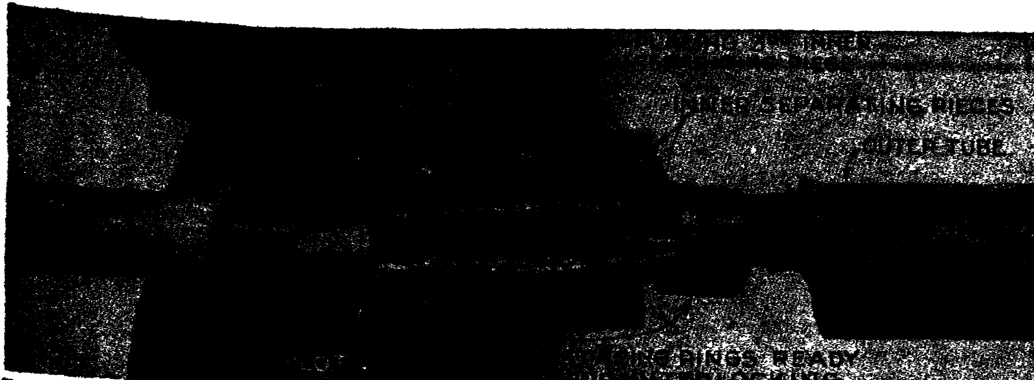


FIG. 6,069.—*Assembling Conducell. First operation:* Placing the inner separating pieces in position. The illustration shows also the two spacing rings ready to be placed in interlocking position, also the outer seamless tube threaded over cables.

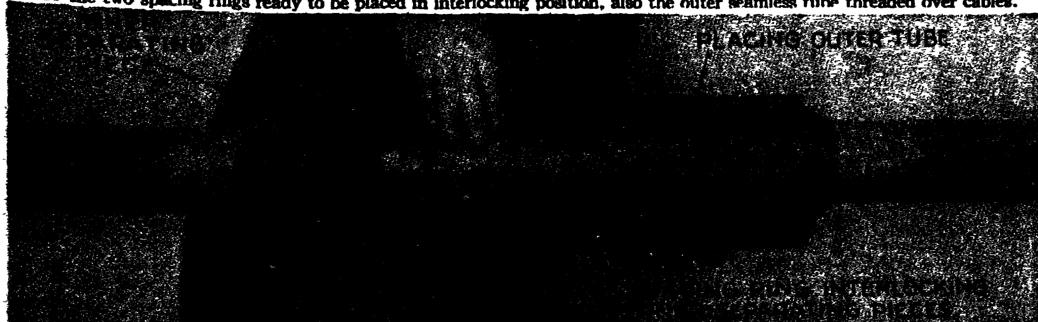


FIG. 6,070.—*Assembling Conducell. Second operation:* Placing the outer seamless tube over the inner separating pieces which have previously been placed in position and locked by the spacing rings.

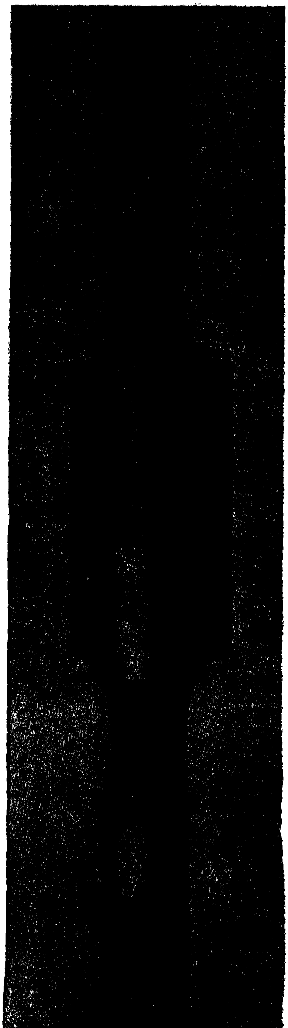
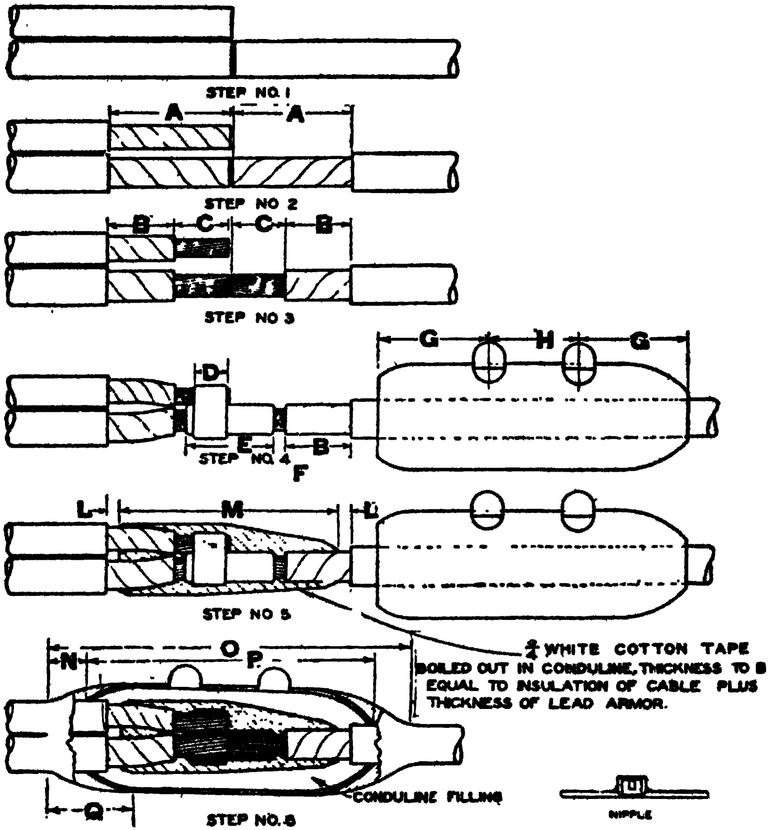


FIG. 6,071.—Appearance of Conducell assembled over the three conductor cable. Note the spacing rings which project beyond the end of the outer seamless tube.

FIG. 6,072.—Cut-away view showing appearance of exterior and interior of three conductor conducell.

SECONDARY HALF DUPLEX JOINTS



CABLE		A	B	C	D	E	F	G	H	SLEEVE	L	M	N	O	P	Q
MAIN	BRANCH															
80 000 CM	80 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7X 2	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	2
200 000 CM	200 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7X $2\frac{1}{2}$	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	$2\frac{1}{4}$
200 000 CM	80 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7X 2	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	2
40 000 CM	40 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{2}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7 x 2	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	2

FIGS. 6,073 to 6,079.—Secondary half duplex joint

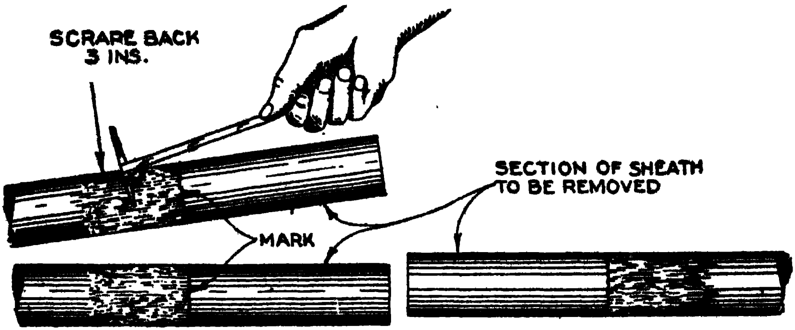
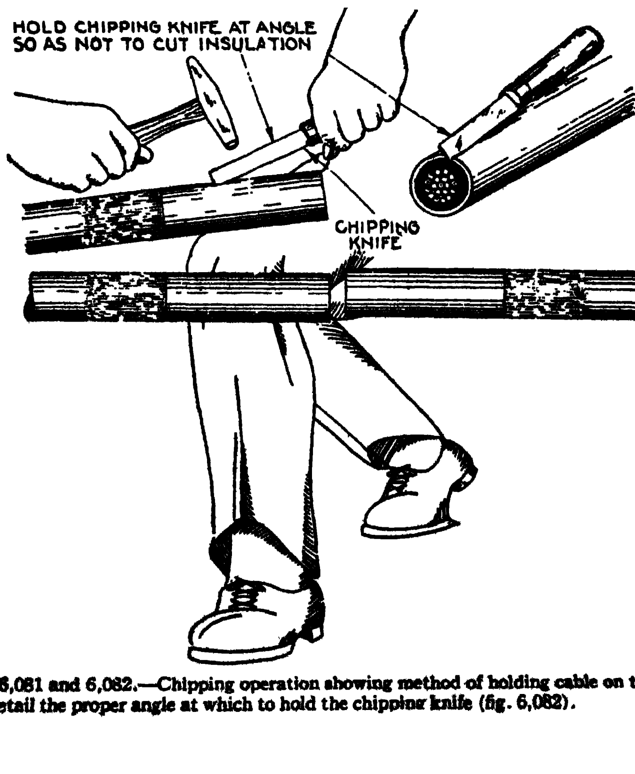


FIG. 6,080.—Scraping lead sheath on cables after they have been cut, aligned and marked.



FIGS. 6,081 and 6,082.—Chipping operation showing method of holding cable on the knee and in detail the proper angle at which to hold the chipping knife (fig. 6,082).

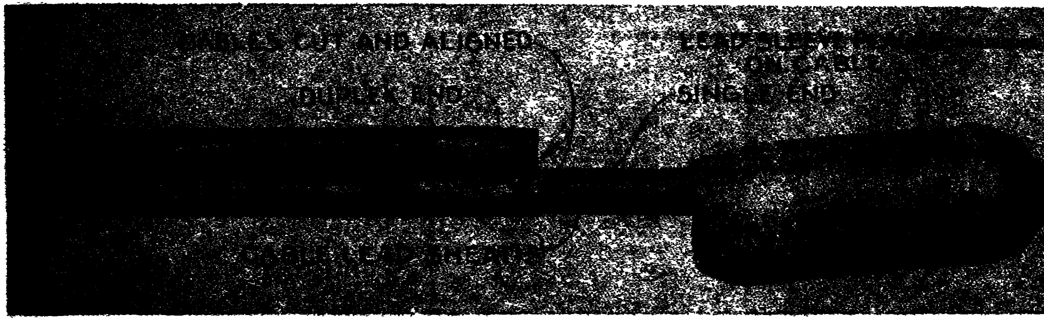


FIG. 6,083.—*Half duplex cable joint 1.* Appearance of cable with ends cut and in position, also sleeve threaded on cable.

Wiping the Sleeve.—Slip the lead sleeve into position and dress the end down to fit over the cable. Apply gummed paper about 3 ins. wide on cable and on the sleeve, n order to confine the wiping to the proper point. Both ends of the sleeve should be soldered to the lead sheath of the cable with a wiped joint.

The operations of placing the sleeve in the proper position and wiping are explained at length for the half duplex joint, later described. Fig. 6,072 shows appearance of the completed three conductor cable joint being cut away to show how the sleeve fits over the joint.

Testing Joint.—After wiping the sleeve test joint to 15 lbs. air pressure with a tire pump and gauge. Applv soapy water to test for leaks.

Filling Joint with Compound.—After the joint has been completed and tested it should be filled through the filling nipple with compound heated to a temperature of 240° Fahr.

In doing this, tilt the joint so that the filling hole will be slightly above the level of the other hole. The compound to be poured through the filling hole until the joint is filled, and about one gallon of hot compound should

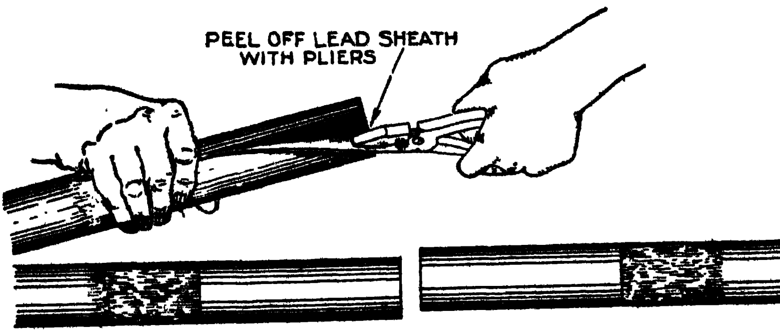


FIG. 6,084.—Removing lead sheath. After ringing and chipping the portion of lead sheath to be removed is easily twisted off with the aid of a pair of pliers.

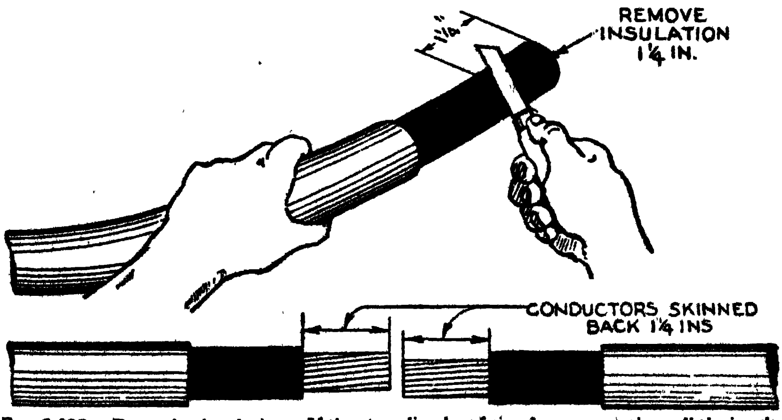


FIG. 6,085.—Removing insulation. If the stranding be of circular cross section, all the insulation is removed at once, but when of the oval form with paper insulation only half should be removed at first so that the shaping operation may be performed without injuring the strands, as fully explained in fig. 6,053.

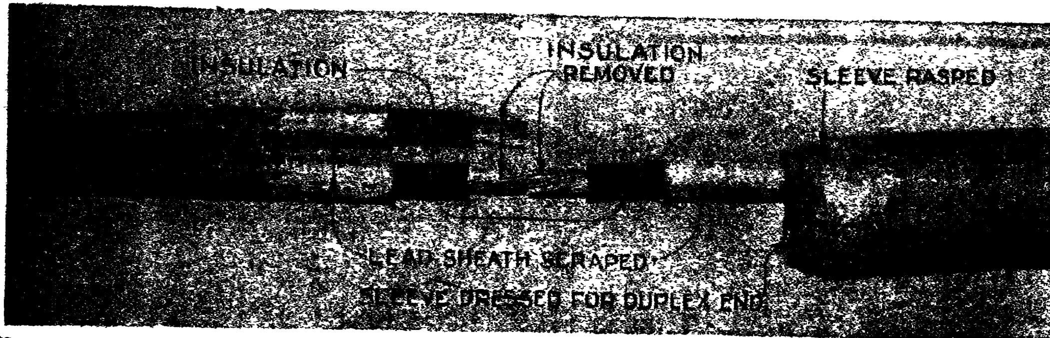


FIG. 6,086.—*Half duplex cable joint 2.* Lead sleeve threaded on cable, sheaths scraped and insulation removed; cable ends in position for connector.

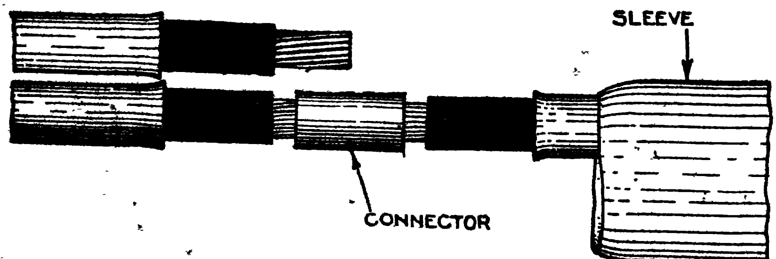


FIG. 6,087.—Conductors in alignment and connector in position over the two abutting conductors.

be allowed to run through the joint in order to boil it out, and remove any moisture which may be present. If there still be frothing of the compound after running the one gallon through the joint, the pouring should be continued until the frothing ceases, as this frothing indicates moisture.

The operation of filling is illustrated for the half duplex cable, fig. 6,100, and differs only in that it is poured through a filling hole instead of a threaded nipple

After the compound has settled give the joint a final fill, close the filling nipple. Be sure the two holes are tightly closed; clean the gummed paper from the lead and do not disturb the joint after this is done.

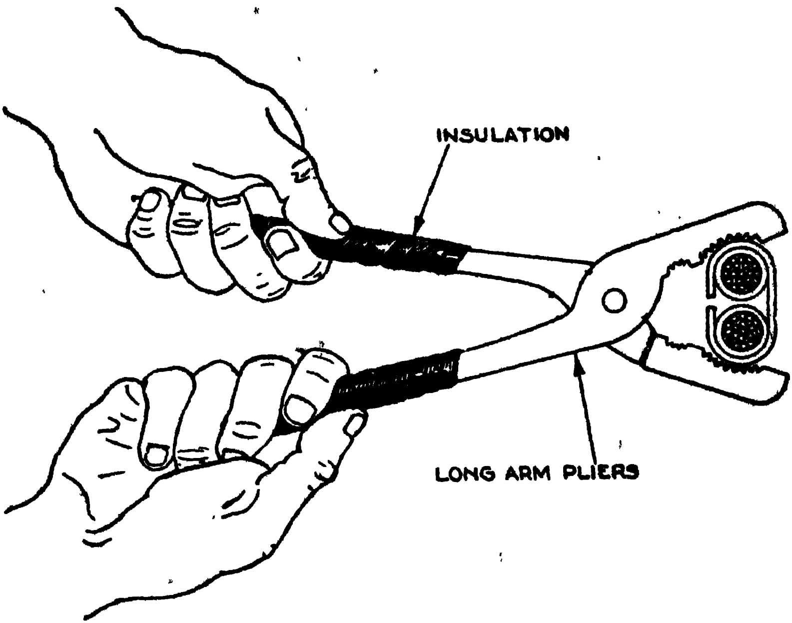


FIG. 6,088.—Method of squeezing on collar with aid of long arm pliers. Note that both hands are used in this operation.

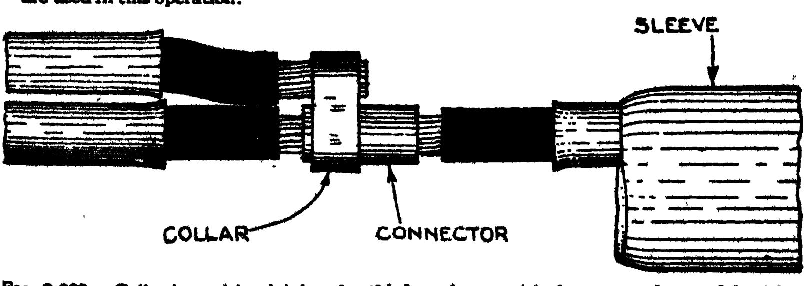


FIG. 6,089.—Collar in position joining the third conductor with the two conductors joined by the connector.

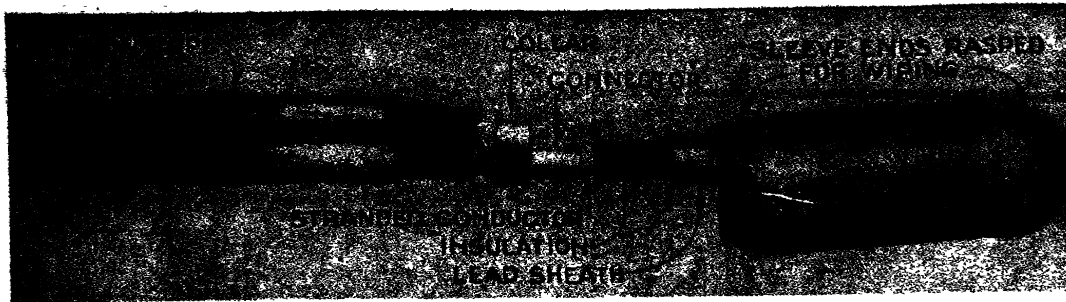


Fig. 6,090.—***Half duplex cable joint 3.*** Appearance of joint after sweating connector and collar. Note the two cables at left held firmly together by friction tape.

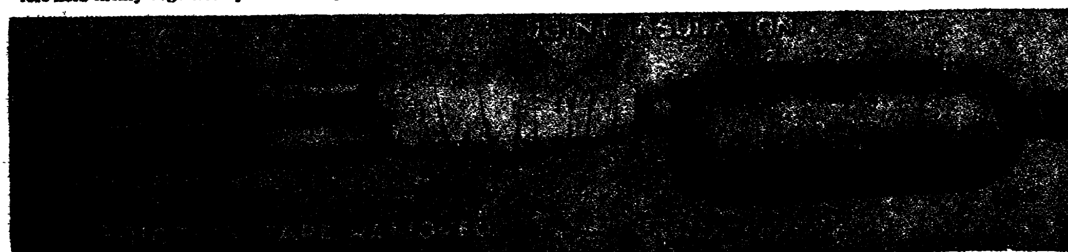


Fig. 6,091.—***Half duplex cable joint 4.*** Appearance of joint after insulating.

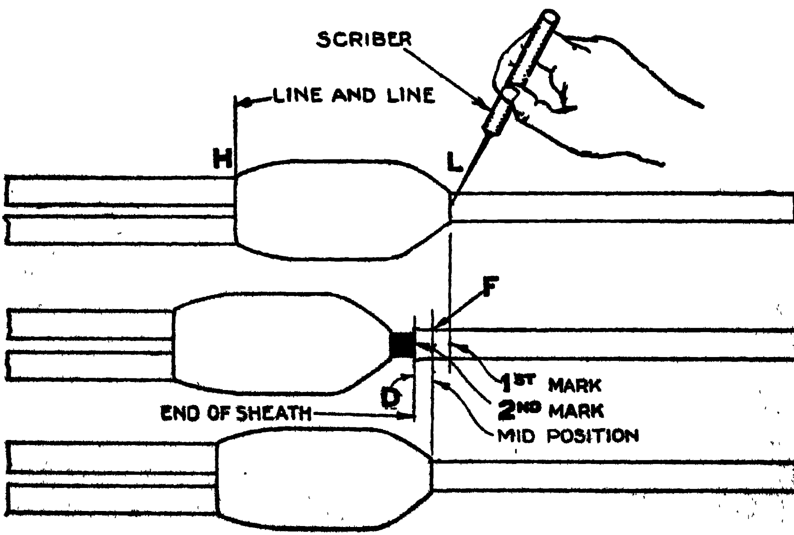
Precautions.—It is important that each operation be made in a neat and workmanlike manner, care being taken that the hands of the jointer are kept dry and that all material used in making the splice is kept in a dry place. No cable should be opened and left exposed to the weather.

110 to 240 Volt Half Duplex Joint.—The cable here used has the following specifications: 200,000 *cm.*; 3/32 rubber and takes a 2½×7 sleeve. Many of the operations performed in making this joint are made in the same way as for the three conductor cable, and accordingly need little or no further explanation.

After training and cutting off the cables, they are marked and scraped as in fig. 6,080.

Next the lead sheath is removed as in figs. 6,081 and 6,082. In fig. 6,082, note that the clipping knife should be held at an acute angle to avoid cutting the insulation.

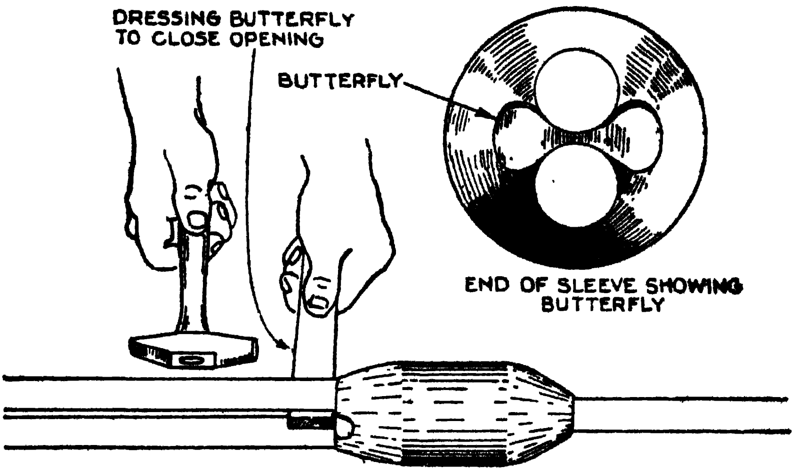
Fig. 6,084 shows the method of twisting off the lead sheath with pair of pliers.



FIGS. 6,092 to 6,094.—Method of centering sleeve over joint. Slide sleeve till its end is *line and line* with the end of the lead sheath as at H, and mark position with scriber as at L, fig. 6,092. Next slide sleeve to left beyond end of sheath and divide the distance between end of sheath (indicated by line D), and position L, in half as indicated by the line F; slide sleeve back to this position. It now overlaps the cables equally at each end, as in fig. 6,094.

Remove conductor insulation back a distance of 1¼ in. as in fig. 6,085.

Now in the half duplex cable a connector and also a collar are



FIGS. 6,095 and 6,096.—Fitting butterfly or filler piece to close up opening at sleeve end. The butterfly should be shaped to fit the sleeve using a rectangular dresser and hammer as in fig. 6,095. The shaping of the other end is easily done with a dresser.

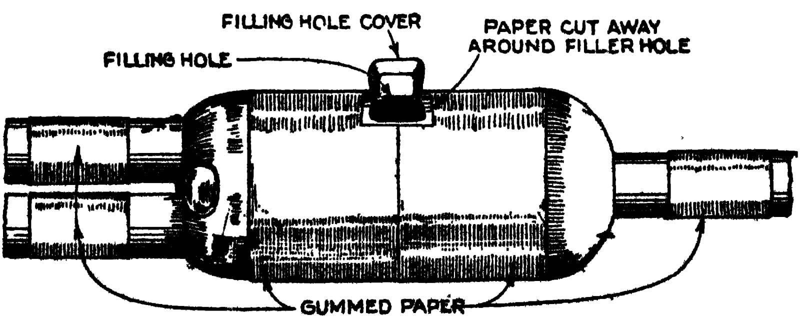


FIG. 6,097.—Application of "paper pasters" to limit the flow of solder in making the wiped joints. These paper pasters are more conveniently applied than the old time "soil" used by plumbers for the same purpose. Any paper with gum on one side will do.

FIG. 6,098.—*Half duplex cable joint 5.* Sleeve in position dressed, and butterfly piece in place ready for wiping.

used. After slipping on the sleeve squeeze the connector around the two butting conductors, as in fig. 6,087. The third conductor being squeezed against the connector by means of the collar, shown in fig. 6,089.

Fig. 6,088 shows the operation of squeezing on the collar with a pair of long arm pliers, using both hands.

The joint is now ready for the sweating operation and this has been thoroughly explained in the instructions for the three conductor cable.

The method of centering the sleeve over the joint with precision is shown in figs. 6,092 to 6,094.

Any opening where the cables come out of the sleeve must be closed up.

At the right side where there is only one cable this is easily done by dressing the sleeve end with a dresser.

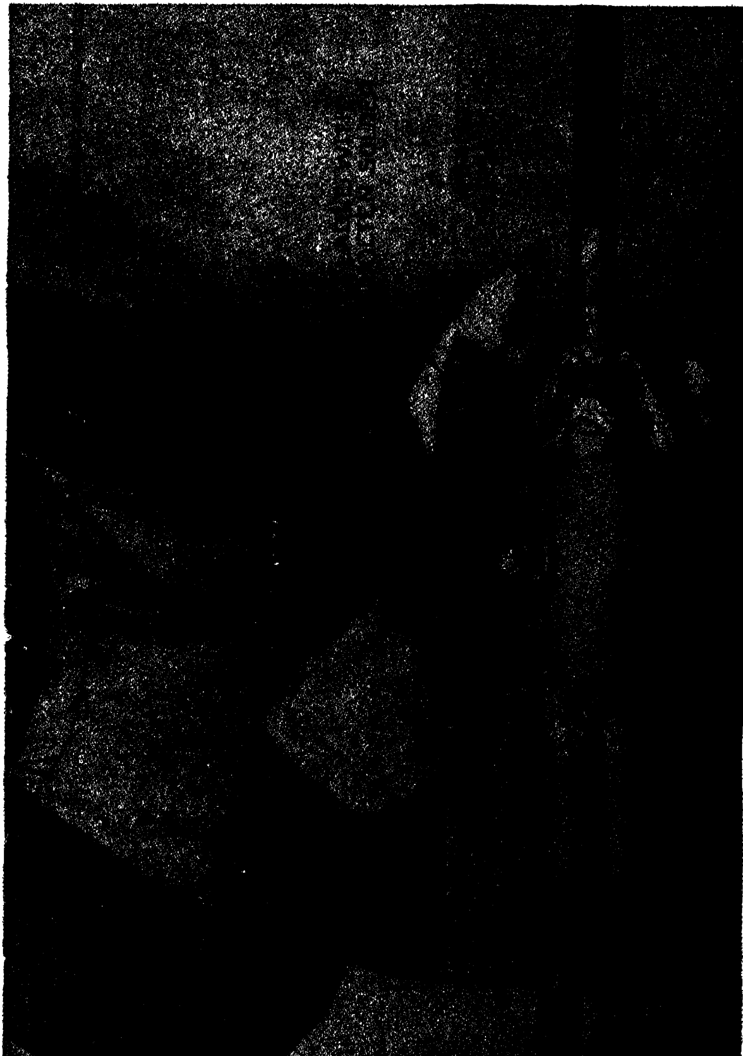


FIG. 6,099.—*Half duplex cable joint 6.* Operation of pouring the molten solder and wiping sleeve end. Note the patch of solder at the duplex end to hold sleeve rigid while wiping

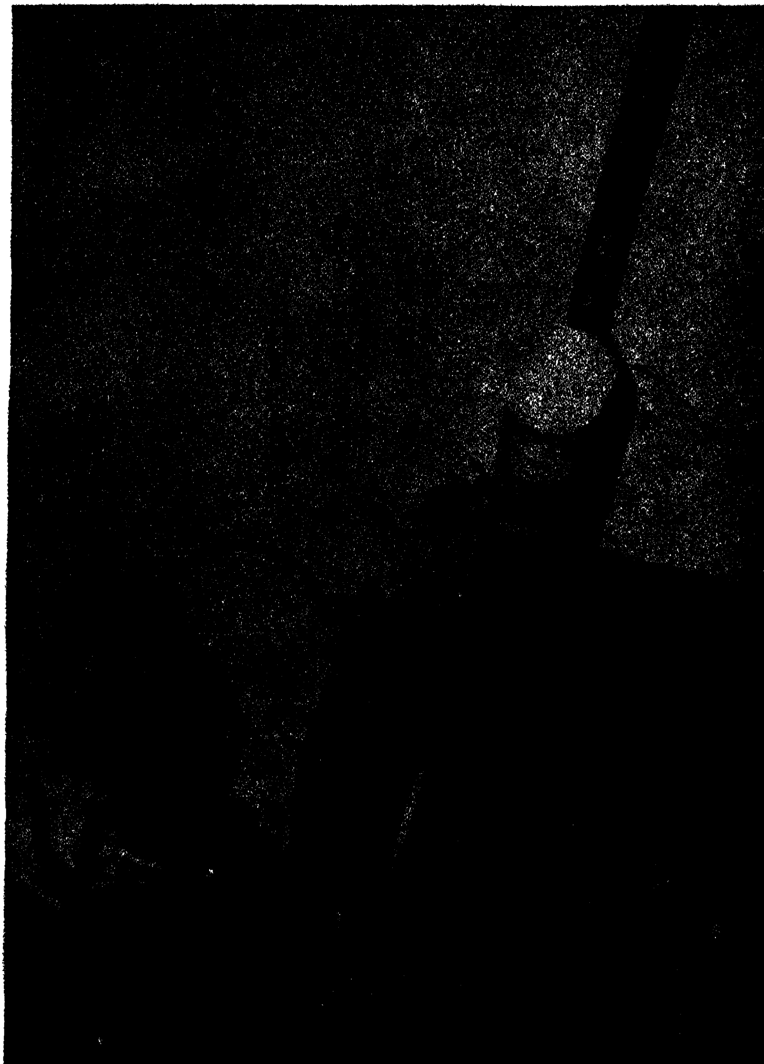


FIG. 6,100.—*Half duplex cable joint 7.* Pouring the hot compound through filling hole into sleeve.

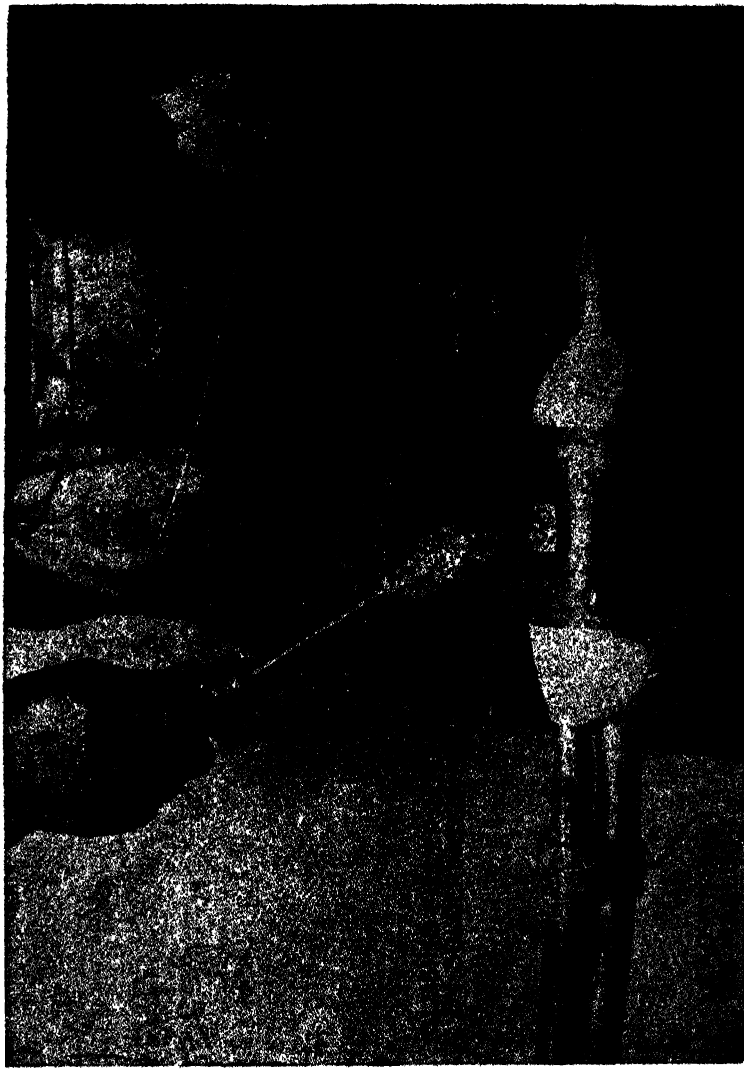


FIG. 6,101.—*Half duplex cable joint 8.* Closing filling hole by soldering cover.

FIG. 6,102.—Appearance of completed half duplex joint.

Now at the other end where the two cables come out there will be an open space between the cables and this is closed with a "butterfly" or filler piece, which is placed at the end of the sleeve and fitted to the opening so as to close the latter. Evidently this is necessary, otherwise in wiping the joint, molten solder would flow into the sleeve.

Mark on the cables and the sleeve the limits of the wiped joints, and paste paper pasters around cables and sleeves so that the edges of the paper register with the marks; as in fig. 6,097 this will limit the flow of solder in wiping up the joints.

After the sleeve has been filled with the compound, as instructed for the three conductor cable, the filler holes are soldered up as in fig. 6,101. Fig. 6,102 shows joint completed.

NOTE.—Jointing for the four wire three phase system, is executed the same as for the three conductor cable explained in this chapter, the fourth or neutral wire being external to the three conductor cable. The system is explained fully in other sections of this series.

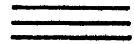
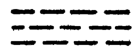
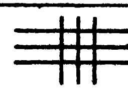
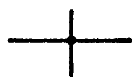
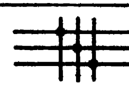
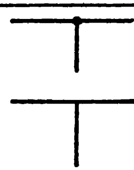
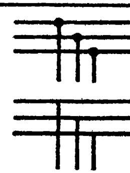
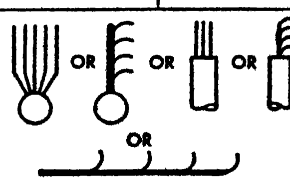
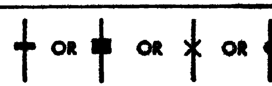
TEST QUESTIONS

1. *Give a classification of various cable joints.*
2. *What preliminary knowledge should the student have before taking up cable jointing?*
3. *Explain in great detail the method of jointing a 13,800 volt, 3 conductor cable.*
4. *What precaution should be taken when bending cables?*
5. *Why are the three insulated conductors wrapped with cambric tape?*
6. *What kind of flux is used on a joint to be sweated?*
7. *Why is a Melrose cord used in wiping a joint?*
8. *What precaution should be taken in penciling?*
9. *Explain in great detail the method of jointing a secondary half duplex cable.*
10. *What tool is used in scraping the ends of a sleeve?*
11. *What fitting is used to joint the second cable at the duplex end?*
12. *What is understood by the expression "line and line?"*
13. *What is the object of the butterfly piece fitted to sleeve?*
14. *How is the sleeve sealed after filling?*

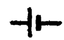
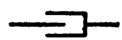
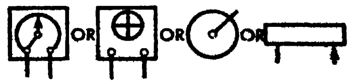
WIRING SYMBOLS

WIRING SYMBOLS

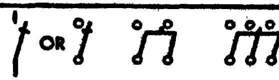
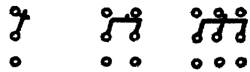
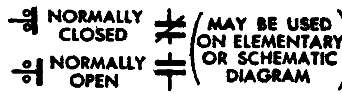
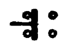
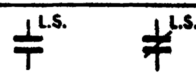
WIRING CONNECTIONS

GROUND		
CONDUCTORS (HEAVY LINES MAY BE USED FOR POWER CIRCUITS; LIGHT LINES FOR CONTROL CIRCUITS)	ONE LINE 	COMPLETE 
FUTURE CONDUCTORS		
CROSSING OF CONDUCTORS NOT CONNECTED		
CROSSING OF CONNECTED CONDUCTORS		
JOINING OF CONDUCTORS NOT CROSSING		OR 
GROUND CONNECTION (GROUND MAY BE DESCRIBED BY NOTE)		
CONDUIT OR GROUPING OF LEADS		
CONDUCTOR WITH POLARITY MARKS		

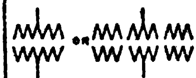
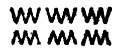
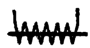
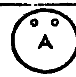
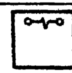
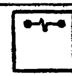
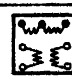
WIRING SYMBOLS (*Continued*)

ALARM		
BELL	ONE LINE 	COMPLETE 
HORN	ONE LINE 	COMPLETE 
BATTERY		
BATTERY	NOTE: THE LONG LINE IS NORMALLY POSITIVE 	
STANDARD CELL		
CAPACITORS		
FIXED CAPACITOR		
FIXED CAPACITOR (AS SHOWN ON COMMUNICATION DIAGRAMS)		
RHEOSTATS		
RHEOSTAT		
RESISTORS		
FIXED OR ADJUSTABLE TYPE RESISTOR		

WIRING SYMBOLS (*Continued*)

SWITCHES	
KNIFE SWITCH ONE, TWO AND THREE POLE (SINGLE THROW)	
KNIFE SWITCH ONE, TWO AND THREE POLE (DOUBLE THROW)	
MISCELLANEOUS SWITCHES	
PUSH BUTTONS	
PUSH BUTTON (OPEN OR CLOSED BY SPRING ACTION)	
PUSH BUTTON (MAINTAINED CONTACT TYPE)	
LIMIT SWITCH CONTACTS	
FUSE	
FUSES	
THERMAL ELEMENT	
TRANSFORMERS	
TRANSFORMER	

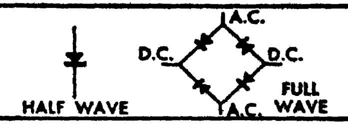
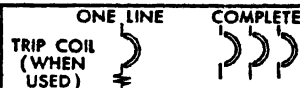
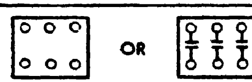
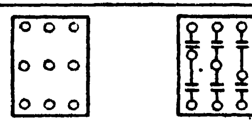
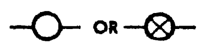
WIRING SYMBOLS (*Continued*)

TRANSFORMERS (CONTINUED)	
ONE PHASE, TWO WINDING TRANSFORMER	ONE LINE  COMPLETE 
POLYPHASE, TWO WINDING TRANSFORMER	 
TRANSFORMERS (MISCELLANEOUS)	 CURRENT  POTENTIAL  AUTO.
INSTRUMENTS & METERS	
INSTRUMENT OR METER	 OR SEE NOTES 
AMMETER	 OR 
VOLTMETER	 OR 
WATTMETER	 OR 

NOTE 1: Letter within Circle or Rectangle Indicates Type of Instrument when only one Type (I or M) is used, Otherwise "I" or "M" appears within Circle with Abbreviation alongside.

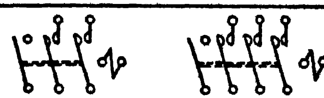
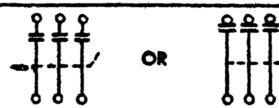
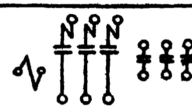
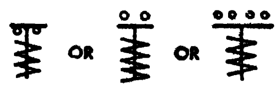
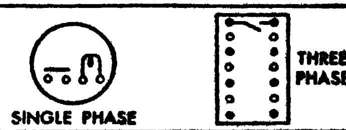
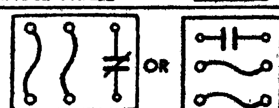
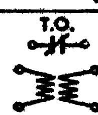
A = Ammeter
AH = Ampere-Hour Meter
CMC = Contact Making Clock
D = Demand Meter
F = Frequency Meter
G = Galvanometer
GD = Ground Detector
I = Indicating
M = Integrating
OHM = Ohmmeter
OSC = Oscillograph
PH = Phase Meter
PI = Position Indicator
PF = Power Factor Meter
RF = Reactive Factor Meter
REC = Recording
RD = Recording Demand Meter
S = Synchroscope
TLM = Telemeter
T = Temperature Meter
VRH = Var-Hour Meter
VAR = Varmeter
V = Voltmeter
WH = Watthour Meter
W = Wattmeter

NOTE 2: For complete Symbol show View approximating Rear View of actual Instrument. Indicate Terminals in Relative Locations and show Potential Terminals with Solid Circle, Current Terminals with Open Circle. Scale Range and Manufacturers Type Numbers may be marked adjacent to Symbol if desired.

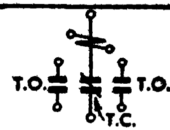
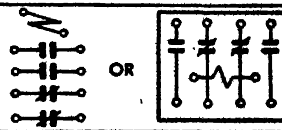
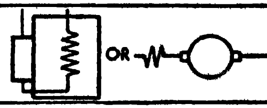
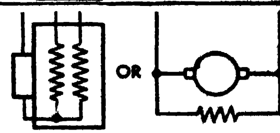
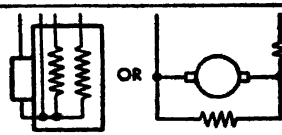
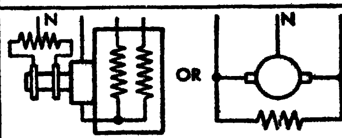
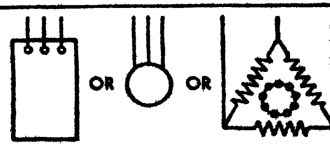
RECTIFIERS	
DRY OR ELECTROLYTIC RECTIFIER (FOR ELEMENTARY OR SCHEMATIC DIAGRAM)	
CIRCUIT BREAKERS	
AIR CIRCUIT BREAKER	
THERMAL AIR CIRCUIT BREAKER	
THREE POLE POWER CIRCUIT BREAKER	
THREE POLE POWER CIRCUIT BREAKER (DOUBLE THROW WITH TERMINALS)	
INDICATING LIGHTS	
INDICATING LAMP	
NOTE: LETTER IN SYMBOL INDICATES COLOR; R = RED, G = GREEN, B = BLUE ETC.	
FLUORESCENT LAMPS	
FLUORESCENT LAMP (WITHOUT AUXILIARIES)	

WIRING SYMBOLS (*Continued*)

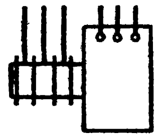
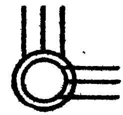
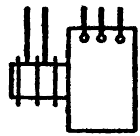
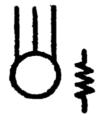
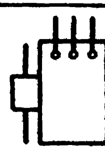
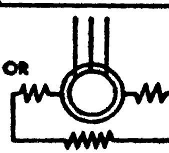
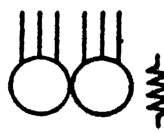
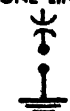
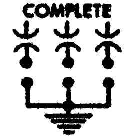
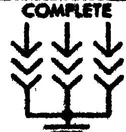
COILS		
FIXED		
ADJUSTABLE TAP OR SLIDE WIRE		
ADJUSTABLE BY FIXED TAPS	 WITH LEADS	 WITH TERMINALS
MAGNETIC CORE INDUCTOR (AS USUALLY REPRESENTED ON COMMUNICATION TYPE DIAGRAMS)	 OR	
OPERATING COIL	 OR	
BLOWOUT COIL		
CONTACTS - ELECTRICAL		
NORMALLY CLOSED CONTACT (NC) NORMALLY CLOSED, DESIGNATES THE POSITION OF THE CONTACTS WHEN THE MAIN DEVICE IS IN THE DE-ENERGIZED OR NON-OPERATED POSITION		
NORMALLY OPEN CONTACT (NO) NORMALLY OPEN, DESIGNATES THE POSITION OF THE CONTACTS WHEN THE MAIN DEVICE IS IN THE DE-ENERGIZED OR NON-OPERATED POSITION		
NO CONTACT WITH TIME CLOSING (TC) FEATURE	 TC	
NC CONTACT WITH TIME OPENING (TO) FEATURE	 TO	

CONTACTORS THE SYMBOLS SHOWN ARE FUNDAMENTAL ONLY AND MAY BE MODIFIED TO SUIT INDIVIDUAL REQUIREMENTS	
CONTACTORS ONE AND TWO POLE CONTACTORS WITH OPERATING COIL	
CONTACTORS TWO AND THREE POLE WITH OPERATING COIL AND AUXILIARY CONTACTS	
THREE POLE MANUALLY OPERATED CONTACTORS WITHOUT BLOWOUT COIL	
THREE POLE ELECTRICALLY OPERATED CONTACTOR WITH BLOWOUT COILS AND TWO NORMALLY OPEN AND ONE NORMALLY CLOSED AUXILIARY CONTACTS	
RELAYS	
RELAY (SOLENOID TYPE)	
RELAY (INDUCTION TYPE)	
RELAY (THERMAL TYPE)	
OVERLOAD RELAY HAVING TWO CURRENT COILS AND ONE NORMALLY CLOSED CONTACT WITH TIMED OPENING	

WIRING SYMBOLS (*Continued*)

RELAYS (CONTINUED)	
MAGNETIC TIME DELAY DROP-OUT RELAY, WITH OPERATING COIL AND TWO NORMALLY OPEN AND ONE NORMALLY CLOSED CONTACTS.	
MULTI-CIRCUIT RELAY WITH TWO NORMALLY OPEN AND TWO NORMALLY CLOSED CONTACTS AND OPERATING COIL	
MACHINES (ROTATING)	
D.C. SERIES MOTOR OR TWO-WIRE GENERATOR	
D.C. SHUNT MOTOR OR TWO-WIRE GENERATOR	
D.C. COMPOUND MOTOR OR TWO-WIRE GENERATOR	
D.C. THREE-WIRE SHUNT GENERATOR	
SQUIRREL CAGE INDUCTION MOTOR	

WIRING SYMBOLS

MACHINES (ROTATING, CONTINUED)		
WOUND ROTOR INDUCTION MOTOR OR GENERATOR	 OR 	
SYNCHRONOUS MOTOR, GENERATOR OR CONDENSER	 OR 	
THREE PHASE SYNCHRONOUS CONVERTER	 OR 	
THREE PHASE DOUBLE WINDING SYNCHRONOUS GENERATOR MOTOR OR CONDENSER		
LIGHTING ARRESTERS		
AUXILIARY SERIES SPHERE-GAP TYPE	ONE LINE 	COMPLETE 
ELECTROLYTIC OR ALUMINUM CELL TYPE	ONE LINE 	COMPLETE 

Useful Information

To find the circumference of a circle, multiply the diameter by 3.1416.

To find the diameter of a circle, multiply the circumference by .31831.

To find the area of a circle, multiply the square of the diameter by .7854.

The radius of a circle $\times$ 6.283185 = the circumference.

The square of the circumference of a circle $\times$ .07958 = the area.

Half the circumference of a circle $\times$ half its diameter = the area.

The circumference of a circle $\times$ .159155 = the radius.

The square root of the area of a circle $\times$ .56419 = the radius.

The square root of the area of a circle $\times$ 1.12838 = the diameter.

To find the diameter of a circle equal in area to a given square, multiply a side of the square by 1.12838.

To find the side of a square equal in area to a given circle, multiply the diameter by .8862.

To find the side of a square inscribed in a circle, multiply the diameter by .7071.

To find the side of a hexagon inscribed in a circle, multiply the diameter of the circle by .500.

To find the diameter of a circle inscribed in a hexagon, multiply a side of the hexagon by 1.7321.

To find the side of an equilateral triangle inscribed in a circle, multiply the diameter of the circle by .866.

To find the diameter of a circle inscribed in an equilateral triangle, multiply a side of the triangle by .57735.

To find the area of the surface of a ball (sphere), multiply the square of the diameter by 3.1416.

To find the volume of a ball (sphere), multiply the cube of the diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

To find the pressure in pounds per square inch at the base of a column of water, multiply the height of the column in feet by .433.

A gallon of water (U. S. Standard) weighs 8.336 pounds and contains 231 cubic inches. A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62.425 pounds at a temperature of about 39° F.

These weights change slightly above and below this temperature.

Tables and Data

In accordance with the standard practice approved by the American Standards Association, the ratio 25.4 mm = 1 inch is used for converting millimeters to inches. This factor varies only two millionths of an inch from the more exact factor 25.40005 mm, a difference so small as to be negligible for industrial length measurements.

Metric Measures

The metric unit of length is the meter = 39.37 inches.
The metric unit of weight is the gram = 15.432 grains.
The following prefixes are used for sub-divisions and multiples: Milli = $\frac{1}{1000}$, Centi = $\frac{1}{100}$, Deci = $\frac{1}{10}$, Deca = 10, Hecto = 100, Kilo = 1000, Myria = 10,000.

Metric and English Equivalent Measures

MEASURES OF LENGTH

Metric		*English*
1 meter	=	39.37 inches, or 3.28083 feet, or 1.09361 yards
.3048 meter	=	1 foot
1 centimeter	=	.3937 inch
2.54 centimeters	=	1 inch
1 millimeter	=	.03937 inch, or nearly 1-25 inch
25.4 millimeters	=	1 inch
1 kilometer	=	1093.61 yards, or 0.62137 mile

MEASURES OF WEIGHT

Metric		*English*
1 gram	=	15.432 grains
.0648 gram	=	1 grain
28.35 grams	=	1 ounce avoirdupois
1 kilogram	=	2.2046 pounds
.4536 kilogram	=	1 pound
1 metric ton 1000 kilograms	=	.9842 ton of 2240 pounds 19.68 cwt. 2204.6 pounds
1.016 metric tons 1016 kilograms	=	1 ton of 2240 pounds

MEASURES OF CAPACITY

Metric		*English*
1 liter (= 1 cubic decimeter)	=	61.023 cubic inches .03531 cubic foot .2642 gal. (American) 2.202 lbs. of water at 62° F.
28.317 liters	=	1 cubic foot
3.785 liters	=	1 gallon (American)
4.543 liters	=	1 gallon (Imperial)

English Conversion Table

Length			
Inches	×	.0833	= feet
Inches	×	.02778	= yards
Inches	×	.00001578	= miles
Feet	×	.3333	= yards
Feet	×	.0001894	= miles
Yards	×	36.00	= inches
Yards	×	3.00	= feet
Yards	×	.0005681	= miles
Miles	×	63360.00	= inches
Miles	×	5280.00	= feet
Miles	×	1760.00	= yards
Circumference of circle	×	.3188	= diameter
Diameter of circle	×	3.1416	= circumference
Area			
Square inches	×	.00694	= square feet
Square inches	×	.0007716	= square yards
Square feet	×	144.00	= square inches
Square feet	×	.11111	= square yards
Square yards	×	1296.00	= square inches
Square yards	×	9.00	= square feet
Dia. of circle squared	×	.7854	= area
Dia. of sphere squared	×	3.1416	= surface
Volume			
Cubic inches	×	.0005787	= cubic feet
Cubic inches	×	.00002143	= cubic yards
Cubic inches	×	.004329	= U. S. gallons
Cubic feet	×	1728.00	= cubic inches
Cubic feet	×	.03704	= cubic yards
Cubic feet	×	7.4805	= U. S. gallons
Cubic yards	×	46656.00	= cubic inches
Cubic yards	×	27.00	= cubic feet
Dia. of sphere cubed	×	.5236	= volume
Weight			
Grains (avoirdupois)	×	.002286	= ounces
Ounces (avoirdupois)	×	.0625	= pounds
Ounces (avoirdupois)	×	.00003125	= tons
Pounds (avoirdupois)	×	16.00	= ounces
Pounds (avoirdupois)	×	.01	= hundredweight
Pounds (avoirdupois)	×	.0005	= tons
Tons (avoirdupois)	×	32000 00	= ounces
Tons (avoirdupois)	×	2000.00	= pounds

English Conversion Table

Energy			
Horsepower	×	33000.	= ft.-lbs. per min.
B. t. u.	×	778.26	= ft.-lbs.
Ton of refrigeration	×	200.	= B. t. u. per min.
Pressure			
Lbs. per sq. in.	×	2.31	= ft. of water (60°F.)
Ft. of water (60°F.)	×	.433	= lbs. per sq. in.
Ins. of water (60°F.)	×	.0361	= lbs. per sq. in.
Lbs. per sq. in.	×	27.70	= ins. of water (60°F.)
Lbs. per sq. in.	×	2.041	= ins. of Hg. (60°F.)
Ins. of Hg (60°F.)	×	.490	= lbs. per sq. in.
Power			
Horsepower	×	746.	= watts
Watts	×	.001341	= horsepower
Horsepower	×	42.4	= B. t. u. per min.
Water Factors (at point of greatest density—39.2°F)			
Miners inch (of water)	×	8.976	= U. S. gals. per min.
Cubic inches (of water)	×	.57798	= ounces
Cubic inches (of water)	×	.036124	= pounds
Cubic inches (of water)	×	.004329	= U. S. gallons
Cubic inches (of water)	×	.003607	= English gallons
Cubic feet (of water)	×	62.425	= pounds
Cubic feet (of water)	×	.03121	= tons
Cubic feet (of water)	×	7.4805	= U. S. gallons
Cubic feet (of water)	×	6.232	= English gallons
Cubic foot of ice	×	57.2	= pounds
Ounces (of water)	×	1.73	= cubic inches
Pounds (of water)	×	26.68	= cubic inches
Pounds (of water)	×	.01602	= cubic feet
Pounds (of water)	×	.1198	= U. S. gallons
Pounds (of water)	×	.0998	= English gallons
Tons (of water)	×	32.04	= cubic feet
Tons (of water)	×	239.6	= U. S. gallons
Tons (of water)	×	199.6	= English gallons
U. S. gallons	×	231.00	= cubic inches
U. S. gallons	×	.13368	= cubic feet
U. S. gallons	×	8.345	= pounds
U. S. gallons	×	.8327	= English gallons
U. S. gallons	×	3.785	= liters
English gallons (Imperial)	×	277.41	= cubic inches
English gallons (Imperial)	×	.1605	= cubic feet
English gallons (Imperial)	×	10.02	= pounds
English gallons (Imperial)	×	1.201	= U. S. gallons
English gallons (Imperial)	×	4.546	= liters

Metric Conversion Table

Length

Millimeters	×	.03937	= inches
Millimeters	÷	25.4	= inches
Centimeters	×	.3937	= inches
Centimeters	÷	2.54	= inches
Meters	×	39.37	= inches (Act. Cong.)
Meters	×	3.281	= feet
Meters	×	1.0936	= yards
Kilometers	×	.6214	= miles
Kilometers	÷	1.6093	= miles
Kilometers	×	3280.8	= feet

Area

Sq. Millimeters	×	.00155	= sq. in.
Sq. Millimeters	÷	645.2	= sq. in.
Sq. Centimeters	×	.155	= sq. in.
Sq. Centimeters	÷	6.452	= sq. in.
Sq. Meters	×	10.764	= sq. ft.
Sq. Kilometers	×	247.1	= acres
Hectares	×	2.471	= acres

Volume

Cu. Centimeters	÷	16.387	= cu. in.
Cu. Centimeters	÷	3.69	= fl. drs. (U.S.P.)
Cu. Centimeters	÷	29.57	= fl. oz. (U.S.P.)
Cu. Meters	×	35.314	= cu. ft.
Cu. Meters	×	1.308	= cu. yards
Cu. Meters	×	264.2	= gals. (231 cu. in.)
Litres	×	61.023	= cu. in. (Act. Cong.)
Litres	×	33.82	= fl. oz. (U.S.P.)
Litres	×	.2642	= gals. (231 cu. in.)
Litres	÷	3.785	= gals. (231 cu. in.)
Litres	÷	28.317	= cu. ft.
Hectolitres	×	3.531	= cu. ft.
Hectolitres	×	2.838	= bu. (2150.42 cu. in.)
Hectolitres	×	.1308	= cu. yds.
Hectolitres	×	26.42	= gals. (231 cu. in.)

Weight

Grams	×	15.432	= grains (Act. Cong.)
Grams	÷	981.	= dynes
Grams (water)	÷	29.57	= fl. oz.
Grams	÷	28.35	= oz. avoirdupois
Kilo-grams	×	2.2046	= lbs.

Metric Conversion Table (Cont.)

Weight

Kilo-grams	×	35.27	= oz. avoirdupois
Kilo-grams	×	.0011023	= tons (2000 lbs.)
Tonneau (Metric ton)	×	1.1023	= tons (2000 lbs.)
Tonneau (Metric ton)	×	2204.6	= lbs.

Unit Weight

Grams per cu. cent.	÷	27.68	= lbs. per cu. in.
Kilo per meter	×	.672	= lbs. per ft.
Kilo per cu. meter	×	.06243	= lbs. per cu. ft.
Kilo per Cheval	×	2.235	= lbs. per h. p.
Grams per liter	×	.06243	= lbs. per cu. ft.

Pressure

Kilo-grams per sq. cm.	×	14.223	= lbs. per sq. in.
Kilo-grams per sq. cm.	×	32.843	= ft. of water (60°F.)
Atmospheres (international)	×	14.696	= lbs. per sq. in

Energy

Joule	×	.7376	= ft. lbs.
Kilo-gram meters	×	7.233	= ft. lbs.

Power

Cheval vapeur	×	.9863	= h. p.
Kilo-watts	×	1.341	= h. p.
Watts	÷	746.	= h. p.
Watts	×	.7373	= ft. lbs. per sec.

Miscellaneous

Kilogram calorie	×	3.968	= B. t. u.
Standard gravity (Sea level 45° lat.)	÷	980.665	= centimeters per sec. per sec.
Frigories/hr. (French)	÷	3023.9	= Tons refrigeration

The following pages show temperatures on Fahrenheit and Centigrade thermometers.

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
-459.4	-273	-21.	-29.4	17.6	-8.	56.	13.3
-436.	-270.	-20.2	-29.	18.	-7.8	57.	13.9
-418.	-260.	-20.	-28.9	19.	-7.2	57.2	14.
-400.	-240.	-19.	-28.3	19.4	-7.	58.	14.4
-382.	-230.	-18.4	-28.	20.	-6.7	59.	15.
-364.	-220.	-18.	-27.8	21.	-6.1	60.	15.6
-346.	-210.	-17.	-27.2	21.2	-6.	60.8	16.
-328.	-200.	-16.6	-27.	22.	-5.6	61.	16.1
-310.	-190.	-16.	-26.7	23.	-5.	62.	16.7
-292.	-180.	-15.	-26.1	24.	-4.4	62.6	17.
-274.	-170.	-14.8	-26.	24.8	-4.	63.	17.2
-256.	-160.	-14.	-25.6	25.	-3.9	64.	17.8
-238.	-150.	-13.	-25.	26.	-3.3	64.4	18.
-220.	-140	-12.	-24.4	26.6	-3.	65.	18.3
-202.	-130.	-11.2	-24.	27.	-2.8	66.	18.9
-184.	-120.	-11.	-23.9	28.	-2.2	66.2	19.
-166.	-110.	-10.	-23.3	28.4	-2.	67.	19.4
-148.	-100	- 9.4	-23.	29.	-1.7	68.	20.
-139.	- 95.	- 9.	-22.8	30.	-1.1	69.	20.6
-130.	- 90.	- 8.	-22.2	30.2	-1.	69.8	21.
-121.	- 85.	- 7.6	-22.	31.	-0.6	70.	21.1
-112.	- 80.	- 7.	-21.7	32.	0.	71.	21.7
-103.	- 75	- 6.	-21.1	33.	+0.6	71.6	22.
- 94.	- 70.	- 5.8	-21.	33.8	1.	72.	22.2
- 85.	- 65.	- 5.	-20.6	34.	1.1	73.	22.8
- 76.	- 60.	- 4.	-20.	35.	1.7	73.4	23.
- 67.	- 55.	- 3.	-19.4	35.6	2.	74.	23.3
- 58.	- 50.	- 2.2	-19.	36.	2.2	75.	23.9
- 49.	- 45.	- 2.	-18.9	37.	2.8	75.2	24.
- 40.	- 40.	- 1.	-18.3	37.4	3.	76.	24.4
- 39.	- 39.4	- 0.4	-18.	38.	3.3	77.	25.
- 38.2	- 39.	0.	-17.8	39.	3.9	78.	25.6
- 38.	- 38.9	+ 1.	-17.2	39.2	4.	78.8	26.
- 37.	- 38.3	1.4	-17.	40.	4.4	79.	26.1
- 36.4	- 38.	2.	-16.7	41.	5.	80.	26.7
- 36.	- 37.8	3.	-16.1	42.	5.6	80.6	27.
- 35.	- 37.2	3.2	-16.	42.8	6.	81.	27.2
- 34.6	- 37.	4.	-15.6	43.	6.1	82.	27.8
- 34.	- 36.7	5.	-15.	44.	6.7	82.4	28.
- 33.	- 36.1	6.	-14.4	44.6	7.	83.	28.3
- 32.8	- 36.	6.8	-14.	45.	7.2	84.	28.9
- 32.	- 35.6	7.	-13.9	46.	7.8	84.2	29.
- 31.	- 35.	8.	-13.3	46.4	8.	85.	29.4
- 30.	- 34.4	8.6	-13.	47.	8.3	86.	30.
- 29.2	- 34.	9.	-12.8	48.	8.9	87.	30.6
- 29.	- 33.9	10.	-12.2	48.2	9.	87.8	31.
- 28.	- 33.3	10.4	-12.	49.	9.4	88.	31.1
- 27.4	- 33.	11.	-11.7	50.	10.	89.	31.7
- 27.	- 32.8	12.	-11.1	51.	10.6	89.6	32.
- 26.	- 32.2	12.2	-11.	51.8	11.	90.	32.2
- 25.6	- 32.	13.	-10.6	52.	11.1	91.	32.8
- 25.	- 31.7	14.	-10.	53.	11.7	91.4	33.
- 24.	- 31.1	15.	- 9.4	53.6	12.	92.	33.3
- 23.8	- 31.	15.8	- 9.	54.	12.2	93.	33.9
- 23.	- 30.6	16.	- 8.9	55.	12.8	93.2	34.
- 22.	- 30.	17.	- 8.3	55.4	13.	94.	34.4

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
95.	35.	134.	56.7	172.4	78.	211.	99.4
96.	35.6	134.6	57.	173.	78.3	212.	100.
96.8	36.	135.	57.2	174.	78.9	213.	100.6
97.	36.1	136.	57.8	174.2	79.	213.8	101.
98.	36.7	136.4	58.	175.	79.4	214.	101.1
98.6	37.	137.	58.3	176.	80.	215.	101.7
99.	37.2	138.	58.9	177.	80.6	215.6	102.
100.	37.8	138.2	59.	177.8	81.	216.	102.2
100.4	38.	139.	59.4	178.	81.1	217.	102.8
101.	38.3	140.	60.	179.	81.7	217.4	103.
102.	38.9	141.	60.6	179.6	82.	218.	103.3
102.2	39.	141.8	61.	180.	82.2	219.	103.9
103.	39.4	142.	61.1	181.	82.8	219.2	104.
104.	40.	143.	61.7	181.4	83.	220.	104.4
105.	40.6	143.6	62.	182.	83.3	221.	105.
105.8	41.	144.	62.2	183.	83.9	222.	105.6
106.	41.1	145.	62.8	183.2	84.	222.8	106.
107.	41.7	145.4	63.	184.	84.4	223.	106.1
107.6	42.	146.	63.3	185.	85.	224.	106.7
108.	42.2	147.	63.9	186.	85.6	224.6	107.
109.	42.8	147.2	64.	186.8	86.	225.	107.2
109.4	43.	148.	64.4	187.	86.1	226.	107.8
110.	43.3	149.	65.	188.	86.7	226.4	108.
111.	43.9	150.	65.6	188.6	87.	227.	108.3
111.2	44.	150.8	66.	189.	87.2	228.	108.9
112.	44.4	151.	66.1	190.	87.8	228.2	109.
113.	45.	152.	66.7	190.4	88.	229.	109.4
114.	45.6	152.6	67.	191.	88.3	230.	110.
114.8	46.	153.	67.2	192.	88.9	231.	110.6
115.	46.1	154.	67.8	192.2	89.	231.8	111.
116.	46.7	154.4	68.	193.	89.4	232.	111.1
116.6	47.	155.	68.3	194.	90.	233.	111.7
117.	47.2	156.	68.9	195.	90.6	233.6	112.
118.	47.8	156.2	69.	195.8	91.	234.	112.2
118.4	48.	157.	69.4	196.	91.1	235.	112.8
119.	48.3	158.	70.	197.	91.7	235.4	113.
120.	48.9	159.	70.6	197.6	92.	236.	113.3
120.2	49.	159.8	71.	198.	92.2	237.	113.9
121.	49.4	160.	71.1	199.	92.8	237.2	114.
122.	50.	161.	71.7	199.4	93.	238.	114.4
123.	50.6	161.6	72.	200.	93.3	239.	115.
123.8	51.	162.	72.2	201.	93.9	240.	115.6
124.	51.1	163.	72.8	201.2	94.	240.8	116.
125.	51.7	163.4	73.	202.	94.4	241.	116.1
125.6	52.	164.	73.3	203.	95.	242.	116.7
126.	52.2	165.	73.9	204.	95.6	242.6	117.
127.	52.8	165.2	74.	204.8	96.	243.	117.2
127.4	53.	166.	74.4	205.	96.1	244.	117.8
128.	53.3	167.	75.	206.	96.7	244.4	118.
129.	53.9	168.	75.6	206.6	97.	245.	118.3
129.2	54.	168.8	76.	207.	97.2	246.	118.9
130.	54.4	169.	76.1	208.	97.8	246.2	119.
131.	55.	170.	76.7	208.4	98.	247.	119.4
132.	55.6	170.6	77.	209.	98.3	248.	120.
132.8	56.	171.	77.2	210.	98.9	249.	120.6
133.	56.1	172.	77.8	210.2	99.	249.8	121.

Decimal and Millimeter Equivalents of Fractional Parts of an Inch

Inches		Inches	mm	Inches		Inches	mm
	1-64	.01563	.397		33-64	.51563	13.097
1-32		.03125	.794	17-32		.53125	13.494
	3-64	.04688	1.191		35-64	.54688	13.890
1-16		.0625	1.587	9-16		.5625	14.287
	5-64	.07813	1.984		37-64	.57813	14.684
3-32		.09375	2.381	19-32		.59375	15.081
	7-64	.10938	2.778		39-64	.60938	15.478
1-8		.125	3.175	5-8		.625	15.875
	9-64	.14063	3.572		41-64	.64063	16.272
5-32		.15625	3.969	21-32		.65625	16.669
	11-64	.17188	4.366		43-64	.67188	17.065
3-16		.1875	4.762	11-16		.6875	17.462
	13-64	.20313	5.159		45-64	.70313	17.859
7-32		.21875	5.556	23-32		.71875	18.256
	15-64	.23438	5.953		47-64	.73438	18.653
1-4		.25	6.350	3-4		.75	19.050
	17-64	.26563	6.747		49-64	.76563	19.447
9-32		.28125	7.144	25-32		.78125	19.844
	19-64	.29688	7.541		51-64	.79688	20.240
5-16		.3125	7.937	13-16		.8125	20.637
	21-64	.32813	8.334		53-64	.82813	21.034
11-32		.34375	8.731	27-32		.84375	21.431
	23-64	.35938	9.128		55-64	.85938	21.828
3-8		.375	9.525	7-8		.875	22.225
	25-64	.39063	9.922		57-64	.89063	22.622
13-32		.40625	10.319	29-32		.90625	23.019
	27-64	.42188	10.716		59-64	.92188	23.415
7-16		.4375	11.113	15-16		.9375	23.812
	29-64	.45313	11.509		61-64	.95313	24.209
15-32		.46875	11.906	31-32		.96875	24.606
	31-64	.48438	12.303		63-64	.98438	25.003
1-2		.5	12.700	1		1.00000	25.400